STATE OF ARIZONA ENHANCED HAZARD MITIGATION PLAN

INTERIM DRAFT – COMMUNITY PROFILES AND HAZARD IDENTIFICATION / PROFILES

Submitted to:

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January 22, 2004

URS

January 22, 2004

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Subject: ***State of Arizona Enhanced Hazard Mitigation Plan – Interim Draft – Community Profiles and Hazard Identification/Profiles***

Dear Barbara,

Submitted herewith for consideration by the Arizona Hazard Mitigation Plan Team is an interim draft of the Community Profiles and Hazard Identification/Profiles sections of the *State of Arizona Enhanced Hazard Mitigation Plan*. This document includes community profile section that covers Arizona and the state's 15 counties. Also provided are the hazard identification and profile sub-sections of the risk assessment section, which includes information on the hazards selected for profiling by the State of Arizona Hazard Mitigation Plan Team based on historical occurrences and future potential for occurrence.

This interim product is intended to conform to the standards established for the Hazard Identification and Risk Assessment functional area of the United States Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). It is also is an initial response to the *Disaster Mitigation Act of 2000*'s Hazard Identification and Risk Assessment requirements.

This document was prepared with significant support from the State of Arizona Hazard Mitigation Plan Team members, other State of Arizona agency representatives, and numerous other Arizona and national resources. We greatly appreciate this support and look forward to comments from the Team members. These comments will be integrated into the final draft document, which will also include numerous other Plan sections that we are in the process of completing.

Please contact us if you have any questions. Thank you.

Sincerely,

URS Corporation

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4. COMMUNITY DESCRIPTIONS

The purpose of this section is to provide basic background information on the State of Arizona, its counties and its communities. At the state level, general information is reviewed concerning geography, climate, population, and economy. At the county level, location, population, development patterns, and planning information is reviewed.

4.1 State Overview

4.1.1 Geography

Arizona is located in the southwestern portion of the United States. It is the sixth largest state in the United States, with 114,006 square miles (Economic and Business Research Program, 2003). Major features of the state are shown in Figure 4-1.

Arizona is typically considered a desert state, but is actually comprised of six major terrestrial ecoregions with widely varying geography (National Geographic, 2003). Each of the following six ecoregions cover varying land areas within the state:

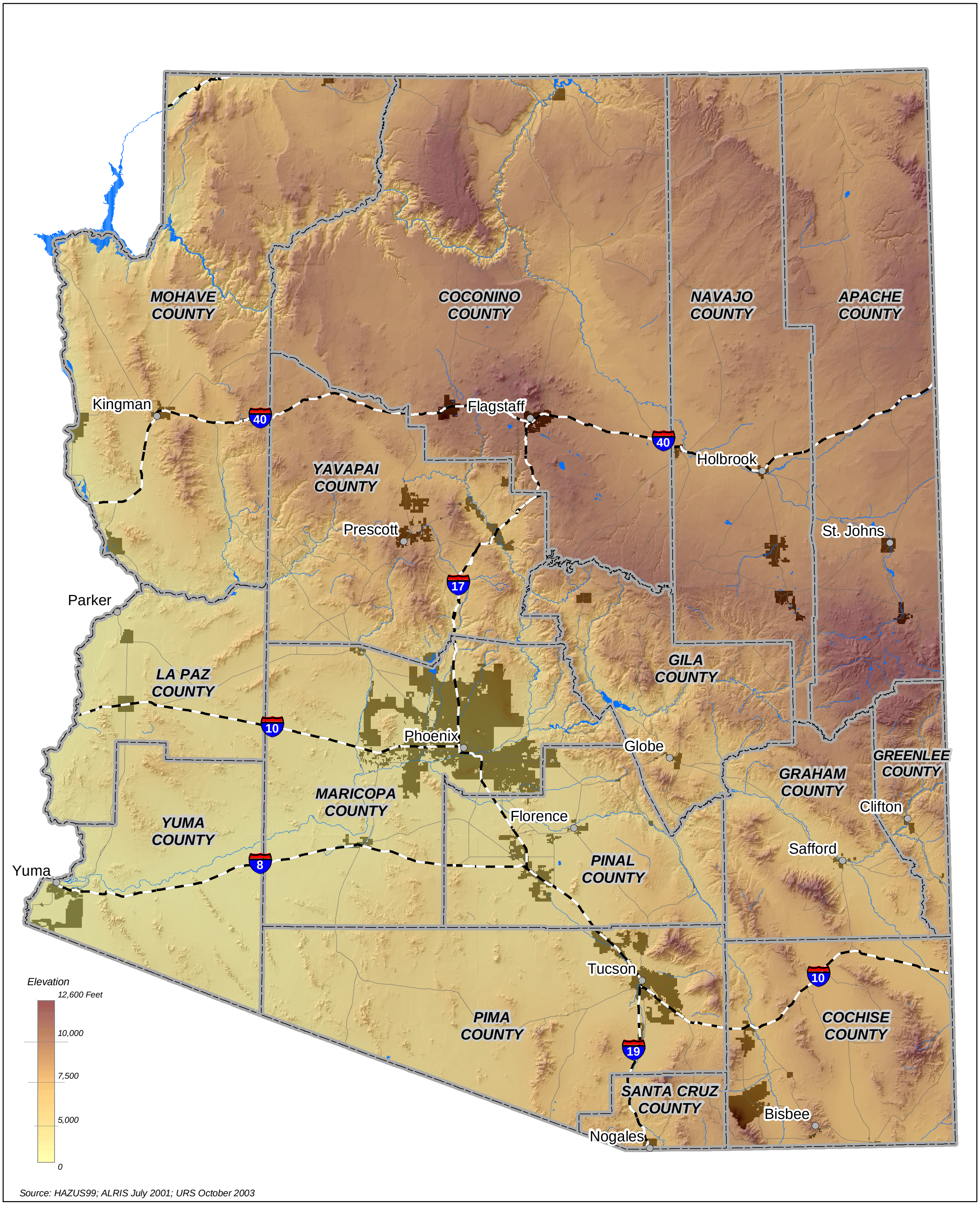
- Arizona Mountain Forests ecoregion
- Chihuahuan Desert ecoregion
- Colorado Plateau Shrublands ecoregion
- Mojave Desert ecoregion
- Sierra Madre Occidental pine-oak forests ecoregion
- Sonoran Desert ecoregion

The Arizona Mountain Forests ecoregion contains a mountainous landscape, much of which is known as the Mogollon Rim, located in approximately the center of the state and running diagonally from southeast to northwest, including portions of Apache, Coconino, Graham, Gila, Greenlee, Maricopa, Mohave, Navajo, Pinal, and Yavapai Counties. This ecoregion includes numerous small to medium-sized cities and towns, such as Eagar, Flagstaff, Globe, Pinetop-Lakeside, Payson, Prescott, and Sedona. Elevations in this zone range from approximately 4,000 to 13,000 feet, resulting in comparatively cool summers and cold winters. Vegetation in this ecoregion is comprised largely of a mix of Scrub Grassland, Mogollon Chaparral Scrubland, Great Basin Conifer Woodland, Rocky Mountain Conifer Forest, and Plains Grassland, as shown in Figure 4-2.

The Chihuahuan Desert ecoregion occupies much of the southeastern portion of Arizona, including portions of Cochise, Gila, Graham, Greenlee, Pima, Pinal, and Santa Cruz Counties. Located within this ecoregion are the small to medium-sized desert communities of Bisbee, Douglas, Safford, and Sierra Vista. The elevation varies in this zone from approximately 3,000 to 4,500 feet. Due to its generally higher elevations the Chihuahuan Desert is cooler than its Sonoran Desert counterpart, with dry summers and occasional winter rains.

The Colorado Plateau Shrublands ecoregion covers much of the northern one-third of the state, including portions or all of Apache, Coconino, Mohave, Navajo, and Yavapai Counties. This ecoregion includes numerous small cities and towns, including Holbrook, Page, and Winslow. Elevations in this zone average around 4,000 to 5,000 feet. Vegetation in this ecoregion is comprised mainly of Plains Grassland and Great Basin Desert scrub, as shown in Figure 4-2. Temperatures can vary widely in this zone, with comparatively warm summers and cool winters.

The Mojave Desert ecoregion covers a relatively small portion of northwest Arizona, including portions of Coconino and Mojave Counties. This ecoregion includes the communities of Kingman and Bullhead City, as well as a portion of the lower Grand Canyon. The elevation varies in this ecoregion from 1,500 feet to nearly 4,000 feet on some mountains. Typically the climate in this ecoregion is very hot and dry during the summer and comparatively warm during the winter.



LEGEND

- Interstate
- Highway
- City
- Major Stream
- County
- Lake
- County Seat

0 25 50
Miles

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Figure 4-1

Major Features of Arizona

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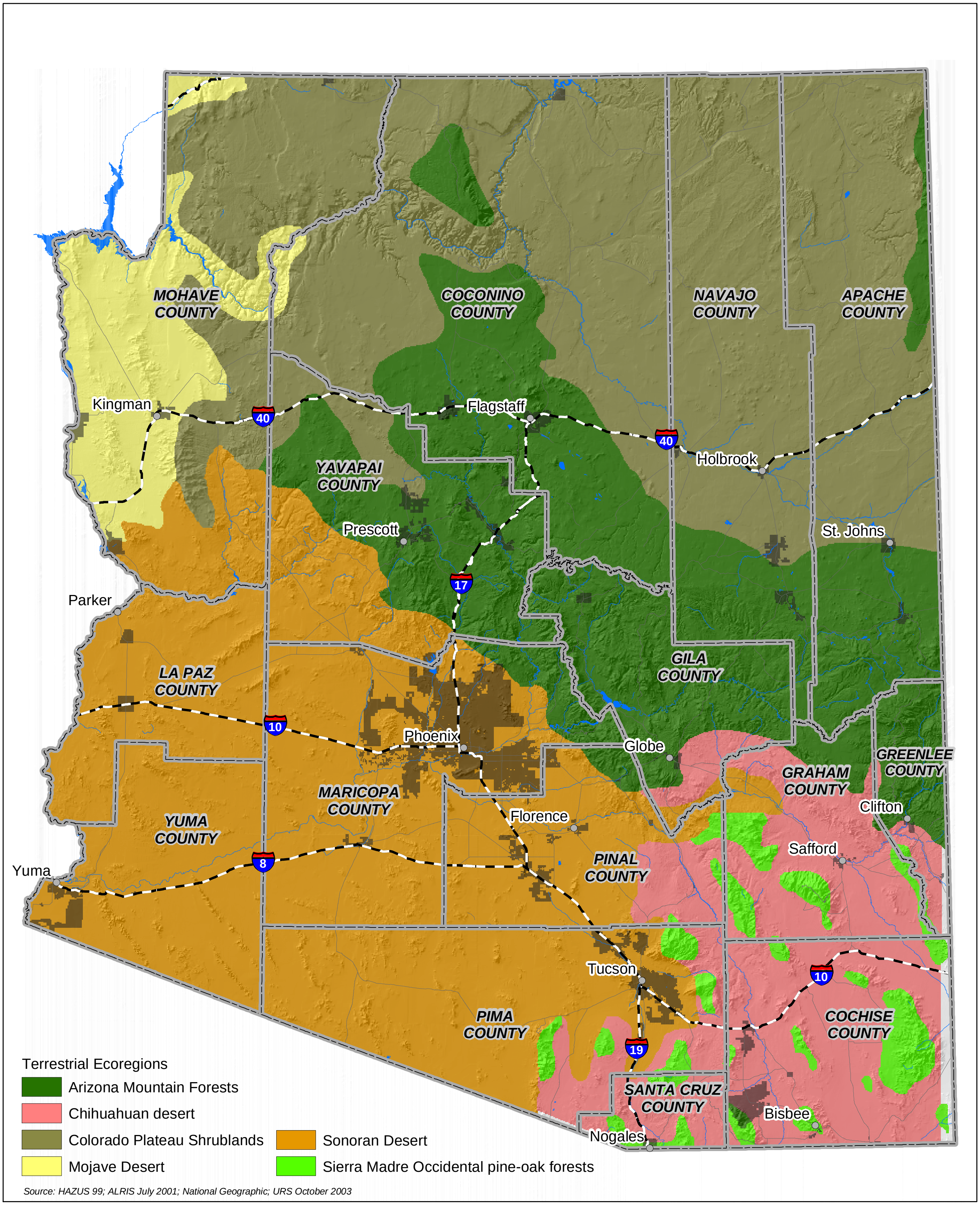

LEGEND

Interstate
Highway
City
Major Stream
County
Lake
County Seat

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0 25 50
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Figure 4-2

Terrestrial Ecoregions of Arizona

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The Sierra Madre Occidental pine-oak forest ecoregion is scattered throughout southeast Arizona, including small portions of Cochise, Graham, Greenlee, Pima, Pinal, and Santa Cruz Counties. Located within this ecoregion is the Town of Nogales, several portions of the Coronado National Forest, as well as the Chiricahua and Galiuro Wilderness areas. As a whole, this ecoregion is considered to have mild winters and wet summers, with variation within these regions due to the fluctuation in elevation associated with the forests.

The Sonoran Desert ecoregion is an arid environment that covers most of the southwestern one-third of the state, including portions or all of Gila, Graham, La Paz, Maricopa, Mojave, Pima, Pinal, Yavapai, and Yuma Counties. Located within this ecoregion are the major metropolitan areas of Phoenix and Tucson as well as numerous smaller towns and cities such as Florence, Parker, and Yuma. The elevation varies in this zone from approximately sea level to 3,000 feet. Vegetation in this zone is comprised mainly of Sonoran Desert Scrub, as shown in Figure 4-2. Typically the climate in this zone is hot and dry during the summer and comparatively warm during the winter.

The primary component of the Arizona Mountain Forests is the Mogollon Rim, a mountainous area that is the major landform defining the northern from the southern portions of the state. The White Mountains in the central eastern part of the state are another large mountainous area. There are also a series of "mountain islands" in the southeastern corner of the state, including the Graham Mountains. Each of these mountainous areas is associated with relatively dense vegetation, ranging from high grasslands to Ponderosa Pine forests.

Arizona also contains a number of rivers, the largest of which is the Colorado, which runs year round and defines most of the western border of the state. The Colorado River has also created the Grand Canyon, which acts as a major barrier to movement in the northwestern portion of the state. Other large rivers, most of which are controlled via dams and run only occasionally, include the Aqua Fria, Gila, Salt, and the Verde Rivers.

4.1.2 Climate

Arizona's geography results in an extreme climate in comparison with other states and also between locations within the state itself. The state's extreme climate is a major contributor to a number of natural hazards in Arizona, including floods, drought and wildfires.

As shown in Table 4-1, average annual temperatures are in the mid-seventies in the Sonoran Desert ecoregion located in the lower half of the state, including cities such as Phoenix, Tucson, and Yuma. By contrast, annual average temperatures are much lower at higher elevations in the Arizona Mountain Forests, Chihuahuan Desert, and Sierra Madre Occidental pine-oak forests ecoregions. Flagstaff, a high mountain community contained within this environment has an average annual temperature of 46.1 degrees. Average annual temperatures for communities that exist in the Colorado Plateau Shrublands ecoregion fall between these two extremes. The town of Holbrook, for example, has an average annual temperature of 56.8 degrees.

Average annual temperatures, however, fail to portray the extreme heat that may be encountered in Arizona. Summer temperatures may exceed 120 degrees in the Sonoran Desert ecoregion, such as in the cities of Phoenix or Yuma, as shown in Table 4-2. Even relatively high elevations in the Arizona Mountain Forests ecoregion may reach high temperatures, such as in Flagstaff which has been known to approach 100 degrees during the summer. Remarkably, these same locations can reach well below freezing (32 degrees) in winter. For example, Flagstaff has dropped to –23 degrees, while even Phoenix winter temperatures have been known to fall into the teens.

These temperature extremes are at least partly the result of Arizona's relatively dry climate. This arid environment is itself a function of a number of factors, including Arizona's separation from nearby major water bodies (i.e., Pacific Ocean, Gulf of California, and Gulf of Mexico), intervening mountainous regions (i.e., Sierra Nevada Mountains), and relatively low elevations across two-thirds of the state.

Table 4-1: Average Temperatures by Month for Stations in Arizona, Selected Cities: Latest Year Available (Degrees Fahrenheit)														
		Month												
City	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Casa Grande	1993	55.7	55.7	61.7	69.6	80.3	86.3	89.7	88.3	83.1	73.7	58.4	52.7	71.3
Clifton	1995	46.5	55.8	57.7	62.2	70.2	80.5	85.6	86.7	79.7	69.2	58.6	47.9	66.7
Flagstaff	1999	34.2	35.1	39.0	37.5	49.4	58.0	64.2	62.1	56.1	47.7	40.5	29.3	46.1
Holbrook	1997	36.2	40.2	50.0	52.8	67.4	71.7	76.6	76.0	72.5	56.4	47.6	34.1	56.8
Kingman	1992	42.7	48.7	50.4	61.4	68.4	75.2	81.3	81.5	76.8	66.9	48.4	41.0	61.9
Miami	1996	48.3	54.1	55.4	63.9	74.2	82.9	84.9	83.1	73.4	66.0	55.4	48.6	65.8
Nogales	1997	45.9	46.8	56.6	57.5	70.8	73.2	79.9	79.3	76.7	62.6	54.1	42.6	62.2
Parker	1997	55.6	58.8	68.3	70.8	84.5	85.2	90.2	93.4	89.3	74.7	63.1	52.1	73.8
Phoenix	1994	57.4	57.9	67.2	74.0	80.0	93.6	94.8	96.1	88.6	74.5	59.1	56.8	75.0
Prescott	1999	41.0	43.1	47.5	46.8	59.6	68.8	72.5	71.0	65.5	58.5	50.5	37.4	55.2
Safford	2000	47.3	52.1	55.7	66.1	76.2	82.4	85.0	82.5	78.6	54.7	47.5	46.2	65.4
St. Johns	1998	36.2	37.5	43.2	46.6	58.9	67.4	74.1	72.7	69.5	54.7	43.8	34.4	53.3
Sierra Vista	2000	51.7	54.5	55.0	65.7	74.8	77.4	78.2	77.3	75.2	62.2	48.0	49.5	64.1
Tucson	1996	56.0	61.0	64.1	71.9	82.2	90.0	90.5	87.4	79	71.6	62.2	54.8	72.6
Yuma	1994	59.4	59.6	68.7	73.6	79.3	93.2	95.7	97.1	90.4	75.7	59.8	56.4	75.7

Source: Economic and Business Research Program, 2003; U.S. National Oceanic and Atmospheric Administration, 2001.

Table 4-2: Highest and Lowest Temperatures of Record by Month in Selected Cities in Arizona Through 1999 (Degrees Fahrenheit)														
	No. of Years of	Month												
City	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Highest Temperature														
Flagstaff	50	66	71	73	80	87	96	97	92	90	85	74	68	97
Phoenix	62	88	92	100	105	113	122	121	116	118	107	93	88	122
Tucson	59	87	92	99	104	107	117	114	112	107	102	93	84	117
Winslow	68	75	78	85	92	101	106	109	103	99	93	80	74	109
Yuma	45	88	97	100	107	116	122	124	120	116	112	98	86	124
Lowest Temperature														
Flagstaff	50	-22	-23	-16	-2	14	22	32	24	23	-2	-13	-23	-23
Phoenix	62	17	22	25	32	40	50	61	60	47	34	25	22	17
Tucson	59	16	20	20	27	38	47	59	61	44	26	24	16	16
Winslow	68	-18	-7	6	16	23	35	44	41	31	13	-1	-12	-18
Yuma	45	24	28	32	41	46	54	63	63	53	35	30	27	24
Source: Economic and Business Research Program, 2003; U.S. National Oceanic and Atmospheric Administration, 1999.														

Table 4-3: Average Relative Humidity by Month in Selected Cities in Arizona Through 1999 (Percent)														
		Month												
City	No. of Years of Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Morning														
Flagstaff	42	74	72	67	64	64	54	68	77	74	71	70	72	70
Phoenix	39	65	56	42	35	35	30	43	50	48	49	56	65	50
Tucson	59	63	54	42	35	35	32	56	65	56	51	54	62	52
Winslow	22	76	61	52	44	44	37	58	65	64	59	66	74	61
Yuma	14	57	52	47	44	44	41	49	55	57	54	56	58	52
Afternoon														
Flagstaff	42	51	41	32	27	27	21	38	44	38	36	43	51	39
Phoenix	39	32	24	17	14	14	12	20	23	23	22	27	34	23
Tucson	59	32	23	16	13	13	13	28	33	27	24	28	34	25
Winslow	22	49	25	20	16	16	13	27	30	29	26	34	47	29
Yuma	14	28	21	17	15	15	14	22	24	24	23	27	32	22
Source: Economic and Business Research Program, 2003; U.S. National Oceanic and Atmospheric Administration, 1999.														

Table 4-4: Normal Monthly Precipitation in Arizona, Selected Cities: 1971-2000 (Index)													
	Month												
City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Flagstaff	2.18	2.56	2.62	1.29	0.80	0.43	2.40	2.89	2.12	1.93	1.86	1.83	22.91
Phoenix	0.83	0.77	1.07	0.25	0.16	0.09	0.99	0.94	0.75	0.79	0.73	0.92	8.29
Tucson	0.99	0.88	0.81	0.28	0.24	0.24	2.07	2.30	1.45	1.21	0.67	1.03	12.17
Winslow	0.46	0.53	0.61	0.27	0.36	0.30	1.18	1.31	1.02	0.90	0.55	0.54	8.03
Yuma	0.38	0.28	0.27	0.09	0.05	0.02	0.23	0.61	0.26	0.26	0.14	0.42	3.01

Source: National Climate Data Center, April 21, 2003. NCDC, NOAA

Table 4-5: Maximum and Average Wind Speed by Month in Selected Cities in Arizona Through 1999 (Miles Per Hour)														
		Month												
City	No. of Years of Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Maximum Wind Speed														
Flagstaff	15	38	34	38	40	46	35	39	30	33	38	39	38	46
Phoenix	14	36	26	43	33	35	31	43	37	37	36	30	26	43
Tucson	51	40	59	41	46	43	50	71	54	54	47	55	44	71
Winslow	34	55	63	61	56	53	52	59	43	41	49	46	52	63
Yuma	40	41	50	43	47	38	42	61	60	57	47	47	47	61
Average Wind Speed														
Flagstaff	32	6.5	6.6	7.1	7.6	7.3	7.0	5.5	5.0	5.6	5.8	6.6	6.6	6.4
Phoenix	54	5.3	5.8	6.6	6.9	7.0	6.7	7.1	6.6	6.3	5.8	5.3	5.1	6.2
Tucson	54	7.9	8.1	8.6	8.9	8.8	8.7	8.4	7.9	8.3	8.2	8.1	7.8	8.3
Winslow	39	7.1	8.5	10.5	11.3	10.8	10.6	9.0	8.4	8.1	7.6	7.3	6.7	8.8
Yuma	28	7.3	7.4	7.9	8.3	8.3	8.5	9.5	8.9	7.3	6.6	6.9	7.2	7.8

Source: Economic and Business Research Program, 2003; U.S. National Oceanic and Atmospheric Administration, 1999.

The average annual relatively humidity in Arizona is low, particularly in the afternoons, as shown in Table 4-3. These low humidity levels contribute to decreased winter temperatures, since the atmosphere is unable to retain heat in the evenings. Furthermore, low humidity levels in the summer contribute to high temperatures and very low rainfall levels, as shown in Table 4-4. Rainfall levels on both an annual basis and during individual months are remarkably low, even at high elevations such as in Flagstaff. It is notable that rainfall periods vary by location, with the Sonoran Desert ecoregion receiving peak monthly rainfall in the winter and the Arizona Mountain Forests ecoregion receiving peak monthly rainfall in the summer.

Average wind speeds are similar across the state, averaging approximately 6 to 9 miles per hour annually, as shown in Table 4-5. However, significant variations exist by location on a monthly basis, as evidenced by Tucson's 71 miles per hour maximum-recorded wind gust.

Climate extremes in Arizona are shown in Table 4-6, including temperatures, precipitation, and snowfall. As evidenced by the table, Arizona has a remarkably broad range of climate extremes.

4.1.3 Population

Arizona's population has increased rapidly since 1990 and is expected to continue growing rapidly. The state's population grew from approximately 3.7 million in 1990 to 5.5 million in 2002, an increase of 1.8 million or 49.3 percent, as shown in Table 4-7. This level of absolute growth is forecast to continue, with the state's population forecast to reach nearly 7.4 million in 2020, an increase of 1.9 million or 34.6 percent over 2002. The state's growth is expected to continue strongly after 2020.

In 2002, 88.2 percent of Arizona's population was urban, with the remaining 11.8 percent rural (Economic and Business Research Program, 2003). These figures were, respectively, 87.5 percent and 12.5 percent in 1990.

Maricopa County is clearly the largest population center in the state and is expected to remain so for the foreseeable future. Maricopa County grew from approximately 2.1 million in 1990 to nearly 3.1 million in 2002, an increase of nearly 1.2 million or 55 percent. In 2002, Maricopa County had 60.2 percent of the state's population, up from 57.9 percent in 1990. With 16.4 percent of the state's population in 2002, Pima County is the only other county that had more than 3.5 percent of the state's population. The state's percentage of population contained in these counties is not forecast to change significantly.

Table 4-6: Arizona Climate Extremes		
Event	**Description**	**Location**
Temperature		
Record Highest Temperature	128°F (29 June 1994)	Lake Havasu City
Record Lowest Temperature	-40°F (7 January 1971)	Hawley Lake
Highest Average Annual Temperature	76.3°F	Lake Havasu City
Lowest Average Annual Temperature	38.3°F	Sunrise Mountain
Consecutive Days Max >= 90	184 days (April-October 1992)	Yuma
Consecutive Days Min <= 32	241 days (October 1976-May 1977)	Fort Valley
Precipitation		
Record Maximum Annual Precipitation	58.92" (1978)	Hawley Lake
Record Minimum Annual Precipitation	0.07"(1956)	Davis Dam
Record Maximum 24-hour Precipitation	11.40" (4-5 September 1970)	Workman Creek
Highest Average Annual Precipitation	38.18 "	Hawley Lake
Lowest Average Annual Precipitation	2.67"	Lake Havasu City
Consecutive Days With Measurable Precipitation	31 days (July-August 1983)	Greer
Consecutive Days with no Measurable Precipitation	352 days (February 1901-January 1902)	Sentinel
Winter Snowfall		
Record Maximum Winter Snowfall	400.9" (1972-73)	Sunrise Mountain
Record Maximum 1-Day Snowfall	38.0" (14 December 1967)	Heber Ranger Station
Highest Average Annual Snowfall	243.0"	Sunrise Mountain

Source: Office of the Climatologist for Arizona.

Table 4-7: Arizona Population, 1990-2040

State/County	1990	2000	2002	2010	2020	2030	2040
Arizona	3,665,228	5,130,632	5,472,750	6,145,108	7,363,604	8,621,114	9,863,578
Counties							
Apache	61,591	69,423	70,105	76,645	85,766	94,707	103,690
Cochise	97,624	117,755	124,040	137,035	149,990	160,049	167,401
Coconino	96,591	116,320	125,420	147,352	169,343	189,868	211,616
Gila	40,216	51,335	53,015	54,603	60,757	66,378	70,163
Graham	26,554	33,498	34,070	43,499	50,673	57,355	63,492
Greenlee	8,008	8,547	8,605	9,605	10,271	10,984	11,634
La Paz	13,844	19,715	20,365	25,096	29,078	31,983	33,899
Maricopa	2,122,101	3,072,149	3,296,250	3,709,566	4,516,090	5,390,785	6,296,219
Mohave	93,497	155,032	166,465	194,403	236,396	270,785	295,045
Navajo	77,658	97,470	101,615	99,979	111,946	123,460	134,323
Pima	666,880	843,746	890,545	1,031,623	1,206,244	1,372,319	1,522,615
Pinal	116,379	179,727	192,395	199,715	231,229	255,695	273,057
Santa Cruz	29,676	38,381	39,840	46,246	55,111	64,459	73,892
Yavapai	68,145	167,517	180,260	198,052	240,849	278,426	305,681
Yuma	106,895	160,026	169,760	171,689	209,861	253,861	300,851

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Arizona has a relatively small number but high proportion of population that may be vulnerable to hazards, as shown in Table 4-8 and Table 4-9. These populations have historically involved the following populations: those that are either very young or very old, households earning very low incomes, home renters, and occupants of very old housing. With an overall population of 5,130,632, the State includes a resident base with approximately 29.5 percent of its inhabitants (1,511,990) under the age of 19, while 13.0 percent (667,607) are over the age of 65. Together these aged and young age groups comprise 2,179,597 residents, or 42.5 percent, of the state's overall population. Furthermore, Arizona's household income levels reflect 548,383 out of 1,901,625 (29.5 percent) of its households earning under $25,000 annually. In addition, of the 1,901,327 occupied housing units in Arizona nearly one third (607,690) are renter occupied, yielding a homeowner-to-renter ratio of 2.1. Expectedly, Arizona's 1.9 million housing units are comparatively aged, with 22.4 percent of Arizona's 2,189,189 housing units (490,710) built before 1970.

Table 4-8: Arizona Populations Potentially Vulnerable to Hazards, 2000

Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,511,990	667,607	1,901,625	548,383
As a % of State	100.0%	29.5%	13.0%	100.0%	28.9%

Source: US Census Bureau.

Table 4-9: Arizona Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership-Owners Vs. Renters		Housing Units	
Jurisdiction	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Source: US Census Bureau.				

In addition to its growing base of permanent residents, Arizona has numerous seasonal visitors, including large numbers of winter visitors and tourists:

- An estimated 300,000 or more winter residents — commonly known as "snowbirds" — were living in Arizona at the height of the 2002-03 winter season (Center for Business Research at Arizona State University, June 2003).
- According to the Arizona Office of Tourism, Arizona had 26.9 million visitors in 2002 (Arizona Republic, July 11, 2003).

More detailed population figures, including those for specific cities and towns, are presented in the sections below on each county.

4.1.4 Economy

Arizona's total employment increased from approximately 1.9 million in 1990 to 2.8 million in 2000, an increase of over 0.9 million or 48 percent, as shown in Table 4-10. The service sector was the largest industry in Arizona in 2000, employing 931,857 persons or 31.8 percent of total state employment. Retail trade was the next largest industry, with 485,052 employees or 16.3 percent. Government was the third largest sector, with 363,317 employees or 13.6 percent. With 225,969 or 11.4 percent, manufacturing is the only remaining sector with over ten percent. Maricopa County is clearly the center of economic activity in Arizona, with 1,896,035 employees or 67.2 percent of total state employment. Pima County is the next largest county, with 444,188 or 15.7 percent. No other County has over 2.6 percent of the state's employment.

Earnings reflect the division of employees in the state, both by industry and by location, as shown in Table 4-11. Services generated nearly $28.3 billion in employee earnings, 29.2 percent of the state total. Retail trade was the next largest industry, with $9.6 billion in employee earnings or 15.8 percent. Government was the third largest sector, with $14.1 billion in employee earnings or 13.6 percent. With $11.9 in employee earnings or 15.8 percent, manufacturing is the only remaining sector with over ten percent. Maricopa County's economic preeminence is confirmed by its $67.8 billion in employee earnings or 72.7 percent of the state total. Pima County is the next largest economic region in Arizona, with $13.0 billion or 13.9 percent. No other county has over 2.0 percent of the state's employee earnings.

Table 4-10: Total Employment in Arizona by Industrial Division, 2000

State/County	Sector										Total
	Agric.	Mining	Const.	Manuf.	TCPU	Whole. Trade	Retail Trade	FIRE	Services	Gov.	
Arizona	67,150	12,658	202,969	225,896	125,125	122,507	485,052	285,847	931,857	363,317	2,822,378
Apache	498E	43E	1,178	164	1,115	301E	2,634	1,454	8,935	6,738	23,060
Cochise	2,373	64	2,849	1,285	1,662	789	8,940	2,926	13,167	15,986	50,041
Coconino	810	153	4,690	2,919	2,012	1,337	15,353	4,726	23,500	15,157	70,657
Gila	458	721E	1,688E	1,150E	682	347	3,863	1,773	6,387	3,346	20,415
Graham	982	19	438	340	274	203	2,242	620	2,719	3,191	11,028
Greenlee	196E	2,497E	882	21	88	93	344	50E	541	616	5,6328
La Paz	884	10E	249	403	315	140E	1,827	393	2,162	1,159	7,542
Maricopa	32,095	2,899	142,288	168,487	93,636	97,247	319,943	216,805	633,905	188,730	1,896,035
Mohave	956	149	4,891	3,503	2,434	1,460	13,097	4,596	16,164	6,767	54,017
Navajo	805	950	2,194E	1,337E	1,968	595	6,658	2,192	9,988	7,176	33,863
Pima	5,983	2,140	28,081	35,144	14,504	12,581	73,947	37,386	159,422	74,660	444,118
Pinal	3,451	1,423	2,046	3,476	1,206	1,343	7,905	2,535	13,632	14276	51,293
Santa Cruz	442	18	640	1,040	1,468	1,891	3,190	844	3,290	3,133	15,956
Yavapai	17,49	1236	7,460	4,199	1,908	2,024	14,322	6,425	23,812	8,850	71,985
Yuma	15,468	66E	3,395	2,428	1,853	2,156	10,787	31,22E	14,233	13,532	67,040

Note: TCPU = Transportation, Communications and Public Utilities. FIRE = Finance, Insurance and Real Estate. E = Data withheld due to disclosure laws, with estimates made by Center for Business Research, L. William Seidman Research Institute, College of Business, Arizona State University.

Source: Center for Business Research, November 2002; US Department of Commerce; Bureau of Economic Analysis.

Table 4-11: Earnings by Place of Work in Arizona by Industrial Division, 2000 ($ mill.)											
	Sector										
State/County	Agric. ($ mill.)	Mining ($ mill.)	Const. ($ mill.)	Manuf. ($ mill.)	TCPU ($ mill.)	Whole. Trade ($ mill.)	Retail Trade ($ mill.)	FIRE ($ mill.)	Services ($ mill.)	Gov. ($ mill.)	Total ($ mill.)
Arizona	1,522.7	541.3	7,212.3	11,931.9	5,350.4	5,785.8	9,620.9	8,976.3	28,266.6	14,070.1	93,278.2
Apache	(1.1)	1.0	24.1	4.9	46.2	2.5	32.6	27.4	216.4	268.4	622.4
Cochise	44.8	2.1	88.7	31.0	70.2	18.3	124.7	34.8	292.7	722.7	1,430.0
Coconino	10.6	3.2	156.3	94.0	78.0	37.6	243.4	64.9	523.0	570.5	1,781.3
Gila	1.4	39.0	53.1	46.5	21.3	9.9	55.3	22.2	127.3	107.6	483.5
Graham	6.6	0.4	15.1	8.0	10.8	4.4	34.6	5.2	52.2	102.9	240.4
Greenlee	0.5	117.1	40.4	0.5	3.1	4.5	4.1	0.9	8.1	16.3	195.4
La Paz	29.4	0.5	7.2	12.3	11.8	3.8	28.8	6.0	50.5	38.8	188.9
Maricopa	696.8	102.2	5,184.9	9,381.8	4,151.5	4,968.8	6,920.8	7,743.9	21,037.9	7,583.1	67,771.6
Mohave	8.3	5.2	157.8	109.1	86.0	45.9	220.2	69.4	383.2	221.8	1,306.8
Navajo	4.2	51.0	64.1	50.0	99.6	14.1	104.0	25.6	199.0	243.4	855.1
Pima	107.3	97.7	973.6	1,834.7	554.0	418.5	1,267.3	763.0	4,139.9	2,799.5	12,955.5
Pinal	160.4	73.4	60.6	121.5	43.7	47.0	131.0	36.3	346.4	443.1	1,463.5
Santa Cruz	3.4	0.3	16.4	35.1	45.0	79.0	55.7	18.5	60.2	137.7	451.2
Yavapai	30.9	45.6	241.3	126.2	58.0	60.9	218.4	98.3	474.8	295.9	1,650.2
Yuma	419.4	2.5	128.6	76.4	71.2	70.6	180.2	60.0	355.1	518.5	1,882.5

Note: TCPU = Transportation, Communications and Public Utilities. FIRE = Finance, Insurance and Real Estate. E = Data withheld due to disclosure laws, with estimates made by Center for Business Research, L. William Seidman Research Institute, College of Business, Arizona State University. Farm earnings can be negative.

Source: Center for Business Research, November 2002; US Department of Commerce; Bureau of Economic Analysis.

4.2 County Overviews

4.2.1 Apache County

Located in the northeastern corner of Arizona, Apache County boasts a diverse geography, and along with it an abundance of recreational opportunities. Originally, Apache County encompassed all of present day Navajo County, part of Gila County and part of Graham County, but by 1895 its size had been reduced to the 11,216 square miles it occupies today. As illustrated in Figure 4-3, the major transportation features in Apache County include Interstate 40, which runs east to west through the County, and United States Highway 60, which runs through the southern portion of Apache County and provides the most direct access to Phoenix. The Apache and Navajo Indian reservations cover more than 65.4 percent of the county, while 21.0 percent of Apache County is publicly owned and only 13.0 percent is privately held. The county's population in 2002 was 70,105, as shown in Table 4-12. Between 1990 and 2000, the county grew at a rate of 12.7 percent, which is substantially lower than the state's growth rate of 40.0 percent during the same time period. There are three incorporated communities in Apache County, including St. Johns, Eagar and Springerville. The population of these and other unincorporated communities in the county is shown below. St. Johns is the county seat, but the largest population resides in the Navajo Nation Indian communities of Ft. Defiance/Window Rock. While growing at a relatively modest pace when compared to Arizona's more urban counties, continued growth in Apache County's incorporated communities can be expected to reflect an overall growth trend in the State.

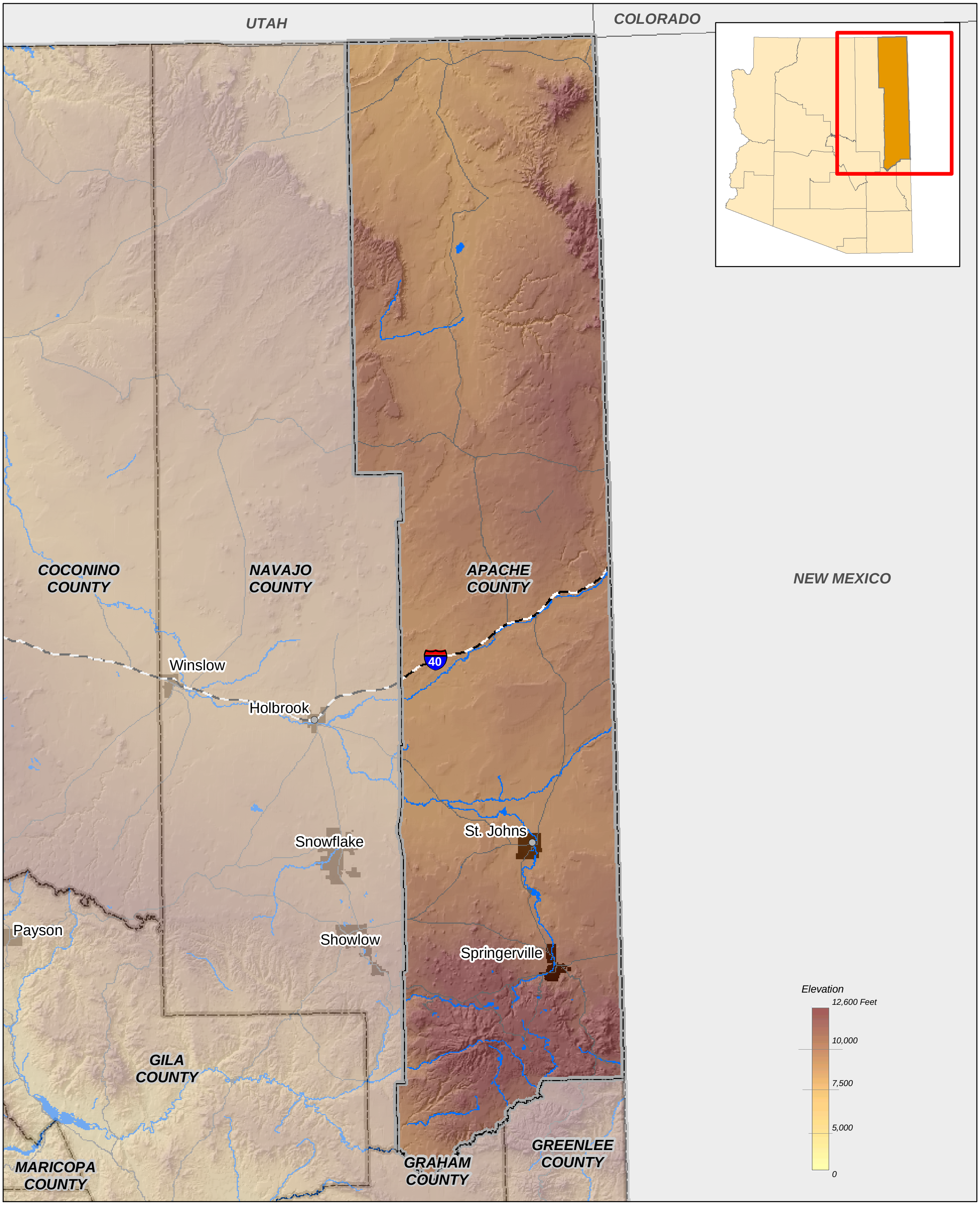
Table 4-12: Apache County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Apache County	61,591	69,423	70,105	76,645	85,766	94,707	103,690
Major Cities							
Chinle, Navajo Nation	5,059	5,568	6,493	7,950	10,037	11,907	13,603
Eagar	4,025	4,103	4,105	6,024	7,182	8,268	9,309
New Lands	N/A	N/A	1,275	1,482	1,721	1,985	2,279
St. Johns	3,294	3,275	3,545	3,517	3,538	3,610	3,737
Springerville	1,802	2,000	1,990	2,338	2,663	2,975	3,282
Window Rock/ Fort Defiance, Navajo Nation	3,306	3,041	4,025	4,742	5,750	6,670	7,523

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997; US Census Bureau.

Apache County, containing a prominent Native American population, has a comparatively small number but high percentage of residents that are potentially vulnerable to hazards. With a total population of 69,423, Apache County contains a small proportion of the state's overall resident base (1.4 percent). As shown in Table 4-13, Apache County has a disproportionately young population, with 41.9 percent (29,072) of its residents less than 19 years of age and 8.3 percent (5,741) over the age of 64. Together these age groups represent more than half of the County's overall population. Apache County's 19,932 households include 10,433 that earn less than $25,000 a year (52.3 percent), a number that provides a stark contrast to the statewide average of 28.8 percent. In addition, of the 19,971 occupied housing units in Apache County more than one quarter (5,127) are renter occupied, yielding a homeowner-to-renter ratio of 2.9 to 1.0. As shown in Table 4-14, this figure compares favorably with the statewide average of 2.1 to 1.0. Apache County has a relatively aged housing stock, with 8,132 of its 31,621 housing units (26.0 percent) constructed prior to 1970, a ratio that compares to the statewide average of 22.4 percent.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

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- City
- County
- County Seat
- Highway
- Major Stream
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Figure 4-3

Major Features of Apache County

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Table 4-13: Apache County Populations Potentially Vulnerable to Hazards, 2000					
	Population			Households	
Jurisdiction	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,511,990	667,607	1,901,625	548,383
Apache County	69,423	29,072	5,741	19,932	10,433
As a % of County	100.0%	41.9%	8.4%	100.0%	52.3%
As a % of State	1.4%	1.9%	0.9%	1.0%	1.9%

Source: US Census Bureau.

Table 4-14: Apache County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		Housing Units	
Jurisdiction	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Apache County	14,844	5,127	31,621	8,132

Source: US Census Bureau.

The civilian labor force in Apache County was 19,589 in 2002 with an unemployment rate of 12.9 percent, which was higher than the state's unemployment rate of 5.8 percent. Services, retail trade, and transportation/public utilities are the major industries with the government sector as the largest employer in the county. The economic base of southern Apache County is well balanced and diversified, and has generated a growing number of skilled workers. The quality of the labor force and low cost of living combine to make the region's average cost of manufacturing the lowest in the state, more than half as much as Phoenix and Tucson.

The Apache County Planning and Zoning office has prepared a *comprehensive plan* that provides direction for the county's future development. The plan was offered to the public for review and comment in the fall of 2003 and will be considered by the Apache County Board of Supervisors in February of 2004.

4.2.2 Cochise County

Cochise County is located in the southeast corner of the state, sharing borders with Santa Cruz, Pima, Graham, and Greenlee counties. With 6,215 square miles, Cochise is as big as the states of Rhode Island and Connecticut combined. Known more for its historic mining communities, Cochise County's origins also lie in the thriving cattle industry and cultivation of specialty crops. The Town of Bisbee is the Cochise County seat, as illustrated along with other significant county features in Figure 4-4. The only major transportation feature in Cochise County is Interstate 10, which runs through the northern portion of the County and provides access west to Tucson/Phoenix and east to El Paso. One of three counties in Arizona without an Indian reservation, individual and corporate ownership account for 40.0 percent of the land in Cochise County, followed by the State of Arizona with 34.6 percent, the U.S. Forest Service and Bureau of Land Management with 22.2 percent, and various other public lands comprise the remaining 3.2 percent.

In the year 2002, the population of the County was 124,040. The County grew at a rate of 21.0 percent between 1990 and 2000, substantially lower than the state's growth rate of 40.0 percent. The populations of the major communities in Cochise County are shown below in Table 4-15. The Towns of Benson, Bisbee, Douglas, Huachuca City, Sierra Vista, Tombstone and Willcox are the seven major communities in the county. Sierra Vista, the biggest city in the county, also has the highest population with 40,415 residents. Population projections for Cochise County suggest very modest growth for the foreseeable future. Much of this new development is expected occur in and around the incorporated community of Sierra Vista. Cochise County's other communities are also expected to grow moderately over the coming decades.

Table 4-15: Cochise County Population, 1990-2040							
Jurisdiction	**1990**	**2000**	**2002**	**2010**	**2020**	**2030**	**2040**
Cochise County	97,624	117,755	124,040	137,035	149,990	160,049	167,401
Major Cities/Communities							
Benson	3,824	4,711	4,745	4,472	4,499	4,574	4,671
Bisbee	6,288	6,090	6,140	6,676	6,692	6,737	6,794
Douglas	12,822	14,312	16,710	16,252	16,458	16,855	17,329
Huachuca City	1,782	1,751	1,800	2,229	2,362	2,469	2,551
Sierra Vista	32,983	37,775	40,415	46,642	52,571	56,757	59,493
Tombstone	1,220	1,504	1,535	1,595	1,611	1,655	1,711
Willcox	3,122	3,733	3,815	3,914	3,944	4,026	4,132

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

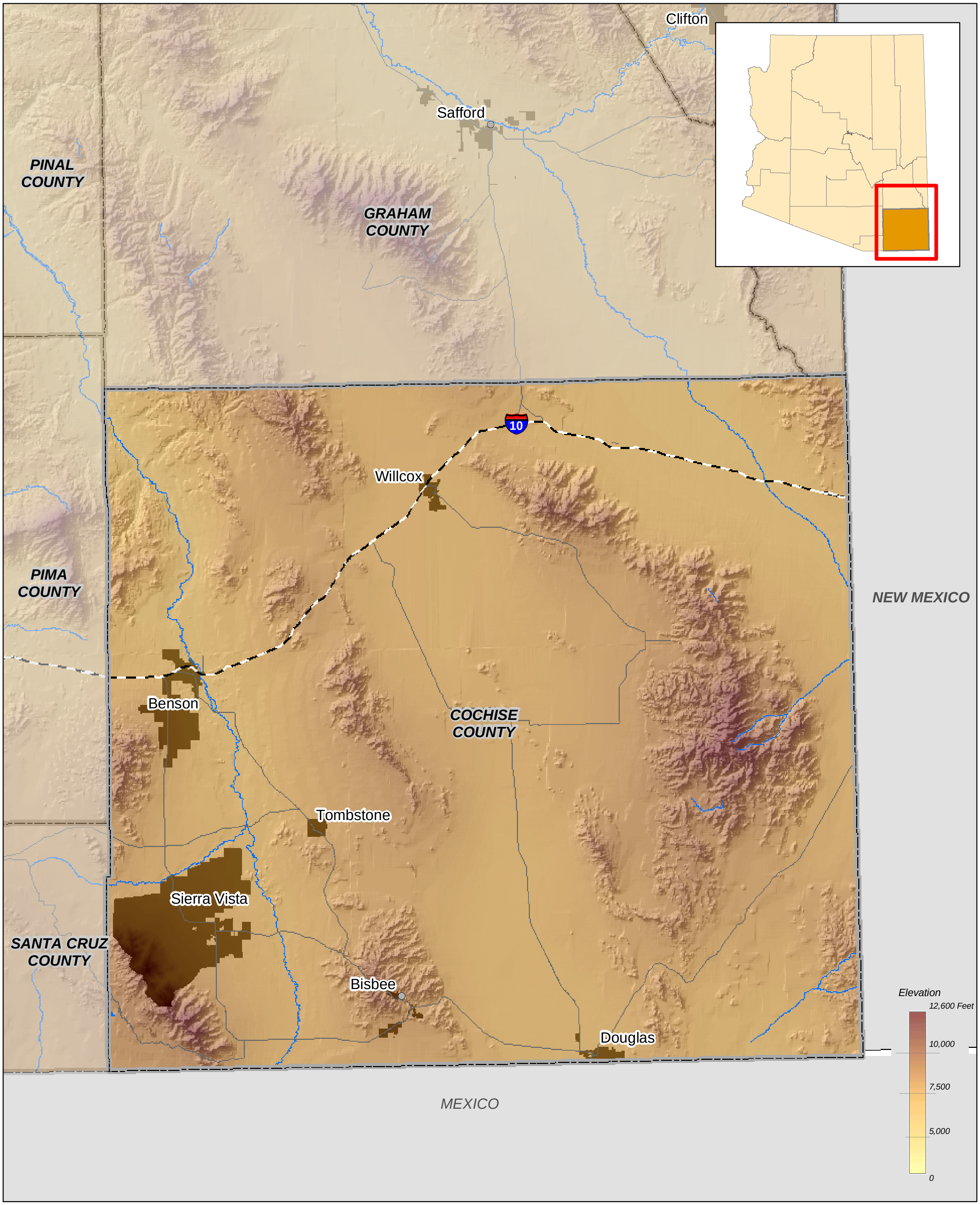
Cochise County has a comparatively small number and modest percentage of residents that are potentially vulnerable to hazards. With a total population of 117,755, Cochise County contains a small proportion of the state's overall resident base (2.3 percent). As illustrated through Table 4-16, Cochise County has a comparatively balanced population, with 29.4 percent (34,666) of its residents less than 19 years of age and 14.8 percent (17,365) over the age of 64. These numbers compare with statewide averages of 29.5 percent and 13.0 percent, respectively. Together Cochise County's vulnerable age groups represent nearly 45.0 percent of the County's overall population, a figure that compares favorably to the state's overall composition of young and aged populations (42.5 percent). Furthermore, Cochise County's 43,896 households include 16,789 that earn less than $25,000 a year (38.3 percent), a number that is considerably higher than the statewide average of 28.8 percent. In addition, of the 43,893 occupied housing units in Cochise County 32.7 percent (14,347) are renter occupied, yielding a homeowner-to-renter ratio of 2.1 to 1.0. As shown in Table 4-17, this figure mirrors the statewide average of 2.1 to 1.0. Reflecting the strong history of the region Cochise County also includes a relatively aged housing stock, with 16,658 of its 51,126 housing units (32.6 percent) constructed prior to 1970, a ratio that compares to a statewide average of 22.4 percent.

Table 4-16: Cochise County Populations Potentially Vulnerable to Hazards, 2000					
	Population			**Households**	
Jurisdiction	**Total**	**<19 years**	**65+ years**	**Total**	**Income <$25,000**
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Cochise County	117,755	34,666	17,365	43,896	16,789
As a % of County	100.0%	29.4%	14.8%	100.0%	38.3%
As a % of State	2.3%	2.3%	2.6%	2.3%	3.1%

Source: US Census Bureau.

Table 4-17: Cochise County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		**Housing Units**	
Jurisdiction	**Homeowners**	**Renters**	**Total**	**Built <1970**
Arizona	1,293,637	607,690	2,189,189	490,710
Cochise County	29,546	14,347	51,126	16,658

Source: US Census Bureau.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

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Figure 4-4

Major Features of Cochise County

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The civilian labor force of Cochise County includes 42,149 workers. Within this employment base only 5.2 percent of eligible workers in Cochise County were unemployed, compared to a statewide unemployment rate of 5.8 percent. The County has a strong history of livestock production, farming and mining throughout most of the region. Fort Huachuca, a United States Army base, has been a significant part of the County's history and remains the largest single employer in Cochise County.

The *Cochise County Comprehensive Plan* was adopted in 1984 and has been revised consistently since its adoption. This document serves to promote orderly and well-planned County growth. The Plan consists of a written document establishing land use, transportation, water conservation and public facility goals and polices and a series of maps that serve as a blueprint for the intensity and type of land uses expected near the incorporated cities and towns and in the outlying rural areas.

4.2.3 Coconino County

Coconino County is located in the north-central portion of Arizona, as illustrated through

Figure 4-5. Encompassing 18,608 square miles, Coconino is the largest in Arizona and is the second largest county in the United States behind California's San Bernardino County. Among the many impressive natural features in Coconino County are the popular Grand Canyon National Park, prehistoric Indian ruins at Wupatki, Navajo National Monument, Mount Humphries, and Lake Powell, with 1,960 miles of shoreline. The primary transportation features of Coconino County include Interstate 40, which runs through the center of the County and connects Flagstaff to points east and west; Interstate 17, which connects with Interstate 40 in Flagstaff and provides access south to Phoenix; and State Highway 89, connecting Coconino County with Utah to the north. Indian Reservations comprise 38.1 percent of land in Coconino County and are home to Navajo, Hopi, Paiute, Havasupai, and Hualapai Tribes. The U.S. Forest Service and Bureau of Land Management control 32.3 percent of the land; the State of Arizona owns 9.5 percent; other public lands comprise 6.8 percent; and the remaining 13.3 percent is owned by individuals or corporations.

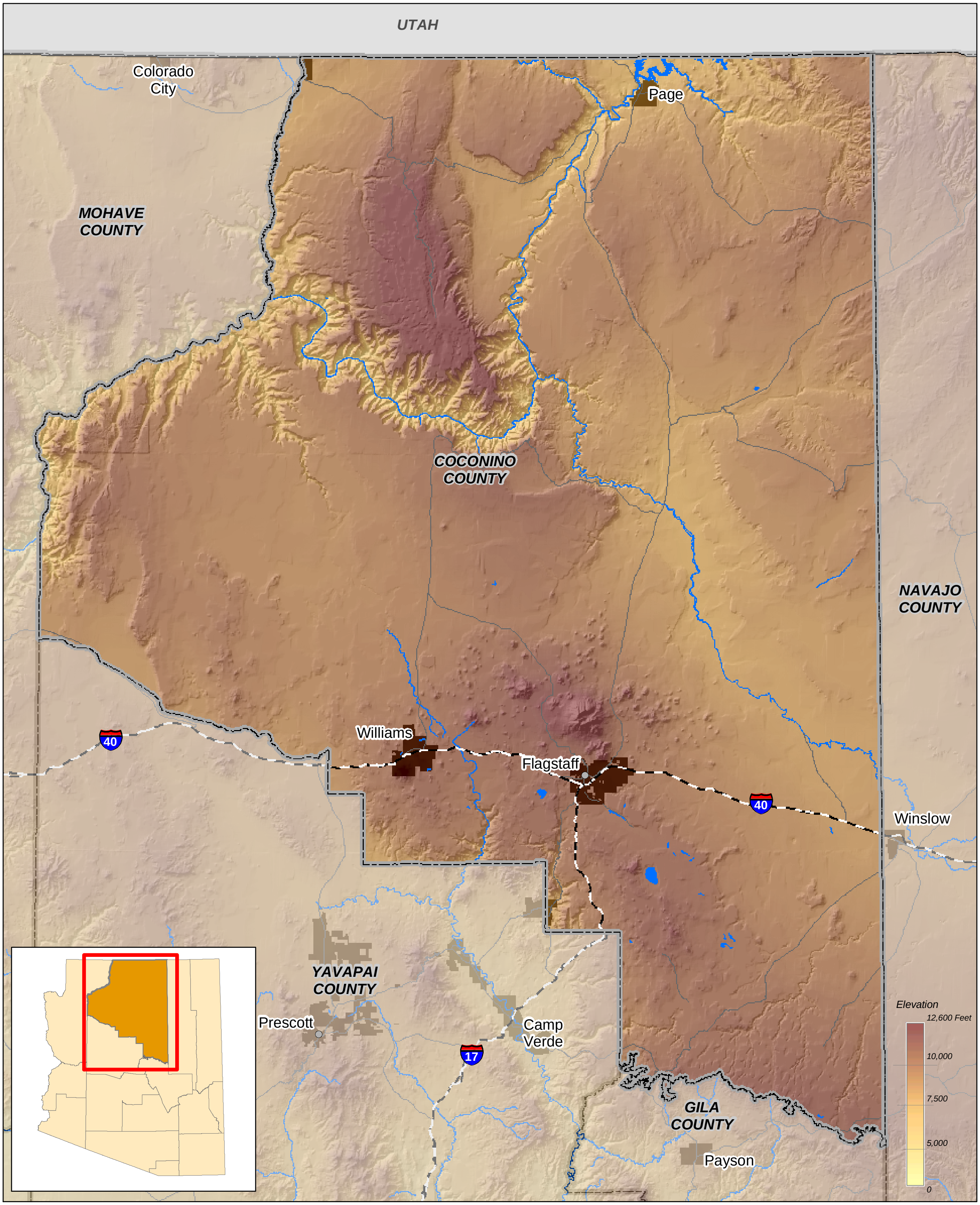
In 2002, the population of Coconino County was 125,420. The county's population grew 20.4 percent between 1990 and 2000, which is only half of the State's overall growth of 40.0 percent for the same period. The populations of the major incorporated communities in Coconino County are shown in Table 4-18. Flagstaff is Coconino's county seat and, with 59,160 residents in 2002, is by far the most populous community among the county's incorporated places. Based upon the population projections illustrated in Table 4-18, many of the communities in Coconino County will continue to experience modest growth. The popular City of Flagstaff, in particular, is projected to grow to over 100,000 residents by the year 2040. Many of the other communities in the County, while continuing to experience growth, are constrained by topographical features.

Table 4-18: Coconino County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Coconino County	96,591	116,320	125,420	147,352	169,343	189,868	211,616
Major Cities/Communities							
Flagstaff	45,857	52,894	59,160	71,981	81,972	91,529	101,907
Fredonia	1,207	1,036	1,090	1,507	1,671	1,811	1,945
Leupp, Navajo Nation	1,503	970	1,045	1,532	1,962	2,338	2,710
Page	6,598	6,809	7,040	11,128	13,057	14,841	16,714
Sedona (Coconino and Yavapai)	7,720	10,192	10,540	12,380	14,611	16,546	18,088
Tuba City, Navajo Nation	7,323	8,225	8,864	11,055	12,520	13,946	15,521
Williams	2,532	2,842	2,910	3,310	3,601	3,925	4,323

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Enhanced Hazard
Mitigation Plan

Figure 4-6

Major Features of Coconino County

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Despite its massive land area Coconino County includes a relatively small number and modest proportion of population that is potentially vulnerable to hazards. As shown through Table 4-19, Coconino County has a young resident base, with 32.4 percent of its citizens less than 19 years of age and only 7.0 percent over the age of 64. These numbers compare with statewide averages of 29.5 percent and 13.0 percent, respectively. Coconino County's lowest household income earners are slightly more prevalent than those statewide, with 31.7 percent of County households earning less than $25,000, compared to 28.8 percent in Arizona. In addition, of the 40,448 occupied housing units in Coconino County 38.6 percent (15,620) are renter occupied, yielding a homeownership-to-renter ratio of 1.6 to 1.0. As shown in Table 4-20, this figure nearly mirrors the statewide average of 2.1 to 1.0. Coconino County's 53,443 housing units reflect construction age that is almost identical to the statewide average, with 22.3 percent (11,931) being built before 1970, balanced with 22.4 percent for Arizona.

Table 4-19: Coconino County Populations Potentially Vulnerable to Hazards, 2000

Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Coconino County	116,320	37,719	8,143	40,386	12,793
As a % of County	100.0%	32.4%	7.0%	100.0%	31.7%
As a % of State	2.3%	2.5%	1.2%	2.1%	2.3%

Source: US Census Bureau.

Table 4-20: Coconino County Dwelling Units Potentially Vulnerable to Hazards, 2000

Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Coconino County	24,828	15,620	53,443	11,931

Source: US Census Bureau.

In Coconino County, 63,175 people constitute the labor force, and the unemployment rate in the county is 5.5 percent, similar but lower than the state average of 5.8 percent for 2002. The government sector has the highest share of employment, closely followed by services and miscellaneous, and trade industries.

In September of 2003 Coconino County formally approved the *Coconino County Comprehensive Plan,* which evaluates the rural, unincorporated, non-tribal areas of the County, and is aimed at reflecting Arizona State's "Growing Smarter" legislation. The previous plan, adopted by the Board of Supervisors in April 1990, has been updated to address the rural-urban development issues in Coconino County.

4.2.4 Gila County

Gila County is located near the center of the Arizona. Illustrated in Figure 4-7, Gila County covers 4,752 square miles and was created in 1881 from portions of Maricopa and Pinal counties. Some of the more notable Gila County land features include the Salt River Canyon, Tonto National Monument, the Mogollon Rim, Tonto Natural Bridge State Park, and Roosevelt Lake. Originally the center of a thriving mining district, the small Town of Globe is now the County seat. United States Highway 60, which crosses the eastern half of the County, is the primary transportation feature in the region. Several, less traveled State Highways also provide access to the various communities in Gila County. The U.S. Forest Service owns 55.5 percent of the land in Gila County. Approximately 37.0 percent belongs to the Apache Indian Tribe; Individuals or corporations own 3.7 percent; the U.S. Bureau of Land Management, 1.9 percent; and the State of Arizona owns 1.0 percent of the land.

As shown in Table 4-21, Gila County's population was 53,015 in 2002, which yields a population growth of 27.6 percent during the 1990's. This number contrasts with the state's overall population increase (40 percent). This table also illustrates the population figures for the major cities and communities in the county. Payson, with a 2002 population of 14,510, is Gila County's most populous community. This is a very rural region of Arizona, and encompasses only a handful of incorporated towns including Globe, Hayden, and Miami. The small population growth that is expected to occur in Gila County through the year 2030 is projected to develop primarily in and around Payson.

Table 4-21: Gila County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Gila County	40,216	51,335	53,015	54,603	60,757	66,378	70,163
Major Cities/Communities							
Globe	6,062	7,486	7,525	8,107	8,661	9,167	9,508
Hayden	909	892	890	912	913	914	915
Miami	2,018	1,936	1,965	2,094	2,127	2,157	2,177
Payson	8,377	13,620	14,510	17,427	21,297	24,833	27,214
San Carlos Apache Reservation	7,294	9,385	9,692	N/A	N/A	N/A	N/A
Winkelman	676	443	450	422	425	428	429

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Gila County includes a comparatively small number and modest proportion of population that is potentially vulnerable to hazards. As shown in Table 4-22, this County has a relatively aged resident base, with only 27.4 percent of its citizens less than 19 years of age 19.8 percent over the age of 64. These numbers compare with statewide averages of 29.5 percent and 13.0 percent, respectively. Gila County's lowest household income earners are slightly more prevalent than those statewide, with 40.7 percent of County households earning less than $25,000, compared to 28.9 percent in Arizona. In addition, of the 20,140 occupied housing units in Gila County only 21.3 percent (4,280) are renter occupied, yielding a homeowner-to-renter ratio of 3.7 to 1.0. As shown in Table 4-23, this figure compares with the statewide average of 2.1 to 1.0. Gila County's 28,189 housing units reflect construction age that is somewhat older than the statewide average, with 28.5 percent (8,043) being built before 1970, compared to 22.4 percent for Arizona.

Table 4-22: Gila County Populations Potentially Vulnerable to Hazards, 2000

Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Gila County	51,335	14,053	10,159	20,165	8,204
As a % of County	100.0%	27.4%	19.8%	100.0%	40.7%
As a % of State	1.0%	0.9%	1.5%	1.1%	1.5%

Source: US Census Bureau.

Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Figure 4-7

Major Features of Gila County

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Table 4-23: Gila County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		Housing Units	
Jurisdiction	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Gila County	15,860	4,280	28,189	8,043
Source: US Census Bureau.				

The civilian labor force of the county in 2002 was 17,274, with an unemployment rate of 5.9 percent, which is slightly higher than the state's unemployment rate of 5.8 percent. Ranching, tourism, logging, recreation, and copper production comprise the major industries of the county with the government sector as the largest employer in the county.

In November of 2003 the Gila County Board of Supervisors approved an update to the *Gila County Comprehensive Master Plan*. The goals, objectives and policies contained in this plan are expected to guide Gila County's efforts to maintain the natural environment of its mountain communities while preparing for intensifying urban issues.

4.2.5 Graham County

Graham County is located in the southeastern portion of Arizona. Graham County was established in 1881 and its largest city, Safford, was incorporated in the same year. Illustrated in Figure 4-8, the San Carlos Indian Reservation covers approximately one-third of County land, with San Carlos Lake known as a popular site for its excellent recreational opportunities The only significant transportation corridor within Graham County is Arizona Highway 70, which runs through the central portion of the County and connects with US Highway 60 to the west. In addition to the significant amount of land owned by the San Carlos Indian Reservation in Graham County, the U.S. Bureau of Land Management owns 38 percent; the State of Arizona, 18 percent; and individual or corporate ownership, 9.9 percent.

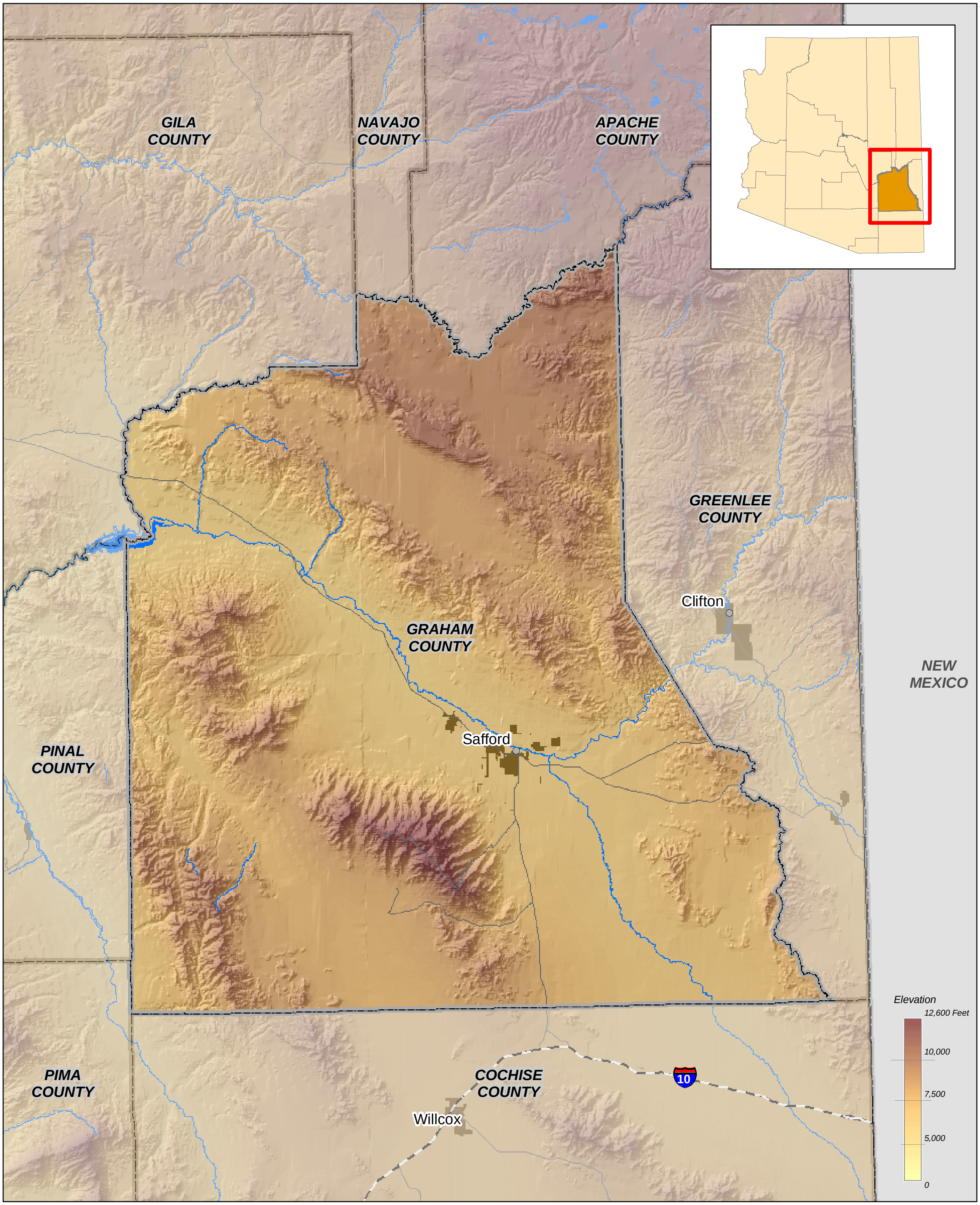
In 2002, the population of Graham County was 26,554, as shown in Table 4-24. The county grew 26.2 percent between 1990 and 2000, which is marginally less active than the state's growth of 40.0 percent in the same period. Safford, Thatcher, and Pima are the only noteworthy incorporated communities in the county. The population of these cities is also referenced in Table 4-24. Safford, Graham's county seat, also has the highest population. Growth projections for Graham County indicate a very moderate rate of population increase throughout the County, with Safford the only community expected to see a substantial gain in population.

Table 4-24: Graham County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Graham County	26,554	33,498	34,070	43,499	50,673	57,355	63,492
Major Cities/Communities							
Pima	1,725	1,989	2,040	2,422	2,669	2,907	3,132
Safford	7,359	9,232	9,395	12,569	13,473	14,853	16,630
Thatcher	3,763	4,022	4,130	5,036	5,763	6,373	6,869

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

Interstate
City
County
County Seat
Highway
Major Stream
Lake

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Figure 4-8

Major Features of Graham County

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Graham County includes a relatively small number and modest proportion of population that is potentially vulnerable to hazards. As shown in Table 4-25, this County has a relatively youthful resident base, with 34.5 percent of its citizens less than 19 years of age and only 11.9 percent over the age of 64. These numbers compare with statewide averages of 29.5 percent and 13.0 percent, respectively. Graham County's lowest household income earners are somewhat more prevalent than those statewide, with almost 42.2 percent of County households earning less than $25,000, compared to 28.9 percent in Arizona. In addition, of the 10,116 occupied housing units in Graham County only 26.8 percent (2,714) are renter occupied, yielding a homeownership-to-renter ratio of 2.7 to 1.0. As shown in Table 4-26, this figure compares with the statewide average of 2.1 to 1.0. Gila County's 11,430 housing units reflect construction age that is somewhat older than the statewide average, with 33.0 percent (3,770) of these units being built before 1970, compared to 22.4 percent for Arizona.

Table 4-25: Graham County Populations Potentially Vulnerable to Hazards, 2000

Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Graham County	33,489	11,545	3,985	10,120	4,375
As a % of County	100.0%	34.5%	11.9%	100.0%	43.2%
As a % of State	0.7%	0.8%	0.6%	0.5%	0.8%

Source: US Census Bureau.

Table 4-26: Graham County Dwelling Units Potentially Vulnerable to Hazards, 2000

Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Greenlee County	7,402	2,714	11,430	3,770

Source: US Census Bureau.

The 10,133 people in the labor force of Graham County are employed primarily in the government and retail trade sectors, with services and miscellaneous occupations representing the other significant labor division in the County. With an unemployment rate of 7.6 percent, Graham County has a slightly higher ratio of unemployed workers than the State.

Reflecting Graham County's rural environment, the preponderance of land in the County is currently zoned Agricultural. A region of Arizona that is not yet facing substantial growth pressures, Graham County is currently in the early stages of developing a *Land Use Plan* to guide future development. Completion of this document is expected sometime in 2005.

4.2.6 Greenlee County

Greenlee County covers 1,837 square miles in the southeastern region of the Arizona. As shown in Figure 4-9, the town of Clifton is Greenlee County's civic nucleus and county seat. The Coronado Trail (U.S. 191), famous for its scenic views, provides the primary roadway feature in Greenlee County. The U.S. Forest Service controls 63.5 percent of the land in Greenlee County; the U.S. Bureau of Land Management, 13.6 percent; the State of Arizona owns 14.8 percent; and individual or corporate interests own only 8.1 percent.

In 2002, the population of Greenlee County was 8,008, as shown in Table 4-27. The county grew at a rate of 6.7 percent between 1990 and 2000, which is significantly lower than the state's overall growth of 40.0 percent during the same period. Clifton, Duncan and Morenci are the three major communities in the county, of which Clifton and

Duncan are incorporated. The population of these cities is shown in Table 4-27. The Town of Clifton, Greenlee's county seat, also has the highest population among the communities in the county. No significant growth is expected to occur in Greenlee County in the foreseeable future.

Table 4-27: Greenlee County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Greenlee County	8,008	8,547	8,605	9,605	10,271	10,984	11,634
Major Cities/Communities							
Clifton	2,840	2,596	2,595	3,278	3,507	3,733	3,921
Duncan	662	812	825	888	949	1,028	1,113
Morenci	1,799	1,879	1,882	1,993	2,133	2,258	2,350

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Greenlee County includes a modest proportion of population that is potentially vulnerable to hazards. As shown in Table 4-28, the County has a relatively young resident base with over 34.4 percent of its citizens less than 19 years of age, but only 9.9 percent over the age of 64. These numbers contrast with statewide totals of 29.5 percent and 13.0 percent, respectively. Greenlee County's household income levels are nearly identical to those statewide, with 28.8 percent of the 3,131 households in the County earning less than $25,000. In addition, of the 3,117 occupied housing units in Greenlee County 49.0 percent (1,526) are renter occupied, yielding a homeownership-to-renter ratio of 1.0 to 1.0. As illustrated in Table 4-29, this figure compares with the statewide average of 2.1 to 1.0. Greenlee County's 3,744 housing units reflect construction age that is proportionately much older than the statewide average, with 45.5 percent being built before 1970, compared to 22.4 percent for Arizona.

Table 4-28: Greenlee County Populations Potentially Vulnerable to Hazards, 2000

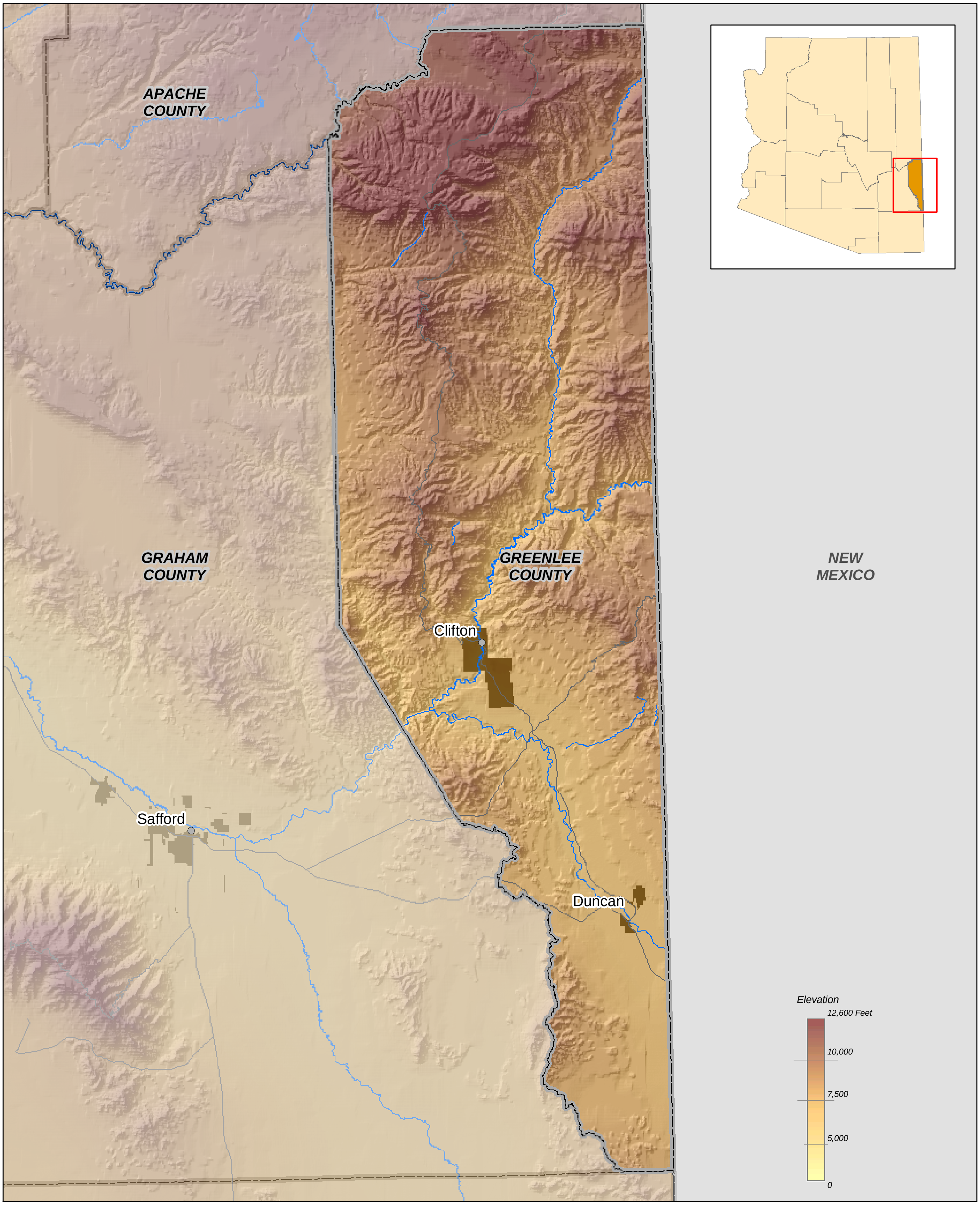
Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Greenlee County	8,547	2,941	849	3,131	901
As a % of County	100.0%	34.4%	9.9%	100.0%	28.8%
As a % of State	0.2%	0.2%	0.1%	0.2%	0.2%

Source: US Census Bureau.

Table 4-29: Greenlee County Dwelling Units Potentially Vulnerable to Hazards, 2000

Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Greenlee County	1,591	1,526	3,744	1,702

Source: US Census Bureau.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Figure 4-9

Major Features of Greenlee County

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Nearly 4,000 people constitute the labor force in the county. Phelps Dodge Corporation, one of the original copper mining companies in the county, remains one of the most active economic engines behind Greenlee County's development. In addition to the major contribution copper mining makes to the County, ranching, agriculture, and tourism are active as well. Greenlee County's unemployment rate of 8.6 percent is somewhat higher than the statewide average of 5.8 percent.

Greenlee County's slow growth history has not created a need for large-scale land use development master planning. The County Administrator administers all localized capital improvement projects including airport growth, bridge replacement, school construction, and solid waste removal.

4.2.7 La Paz County

La Paz County is located in the western part of Arizona. It is the third smallest of Arizona's counties and has the lowest population density with slightly more than four persons per square mile. Of the 4,518 square miles contained in the county, 30 square miles are comprised of water, and the U.S. Bureau of Land Management controls 58.3 percent of the land. The County's general features, which are highlighted by the Colorado River and its attendant tributaries, are shown in Figure 4-10, Interstate 10, which connects Phoenix to the east and Los Angeles to the west, bisects the central region of La Paz County. State Highway 95 and US Highway 60 also provide vital transportation connections to the north, south, and east. The U.S. Bureau of Land Management owns 58.3 percent of La Paz County, with other public lands accounting for 19.5 percent of the County; the state of Arizona owns 8.8 percent of the County; and individual or corporate interests control only 5.3 percent of the County.

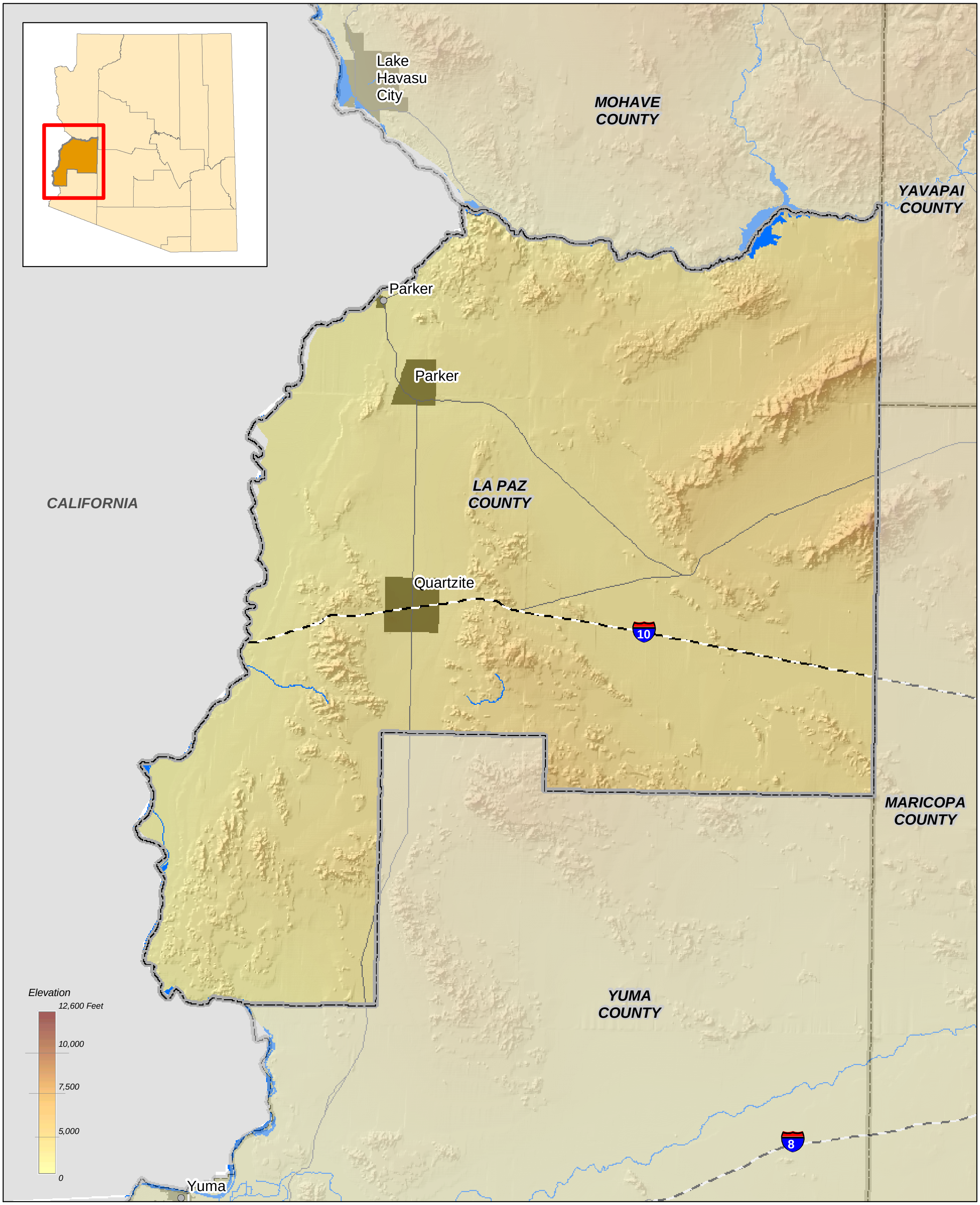
The 2002 population of La Paz County was 20,365, as shown in Table 4-30. The County grew at a rate of 42.4 percent between 1990 and 2000, surpassing the state's overall growth of 40.0 percent. The populations of the major communities located in this region of Arizona are reflective of this moderate growth trend. Parker and Quartzite are the two most populous incorporated communities, and the small Town of Parker is the county seat. The Colorado River Indian Community has the highest population amongst the County's jurisdictions. While experiencing a growth rate that exceeds the State average, La Paz County's small communities are not expected to experience substantial gains in resident population.

Table 4-30: La Paz County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
La Paz County	13,844	19,715	20,365	25,096	29,078	31,983	33,899
Major Cities/Communities							
Bouse	515	615	667	N/A	N/A	N/A	N/A
Colorado River Reservation	3,035	7,466	7,623	N/A	N/A	N/A	N/A
Ehrenberg	1,226	1,357	1,402	2,075	2,671	3,022	3,196
Parker	2,897	3,140	3,250	3,820	4,818	5,357	5,581
Quartzsite	1,876	3,354	3,430	3,668	5,498	6,497	6,921
Salome/Wenden	1,457	2,246	2,320	N/A	N/A	N/A	N/A

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
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Mitigation Plan

Figure 4-10

Major Features of La Paz County

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La Paz County includes a small number and modest proportion of population that is potentially vulnerable to hazards. As shown in Table 4-31, La Paz County's resident population (19,715) occupies only a small share (0.4 percent) of Arizona's total, and reflects a comparatively aged population, with only 23.0 percent of its residents under the age of 19, while 25.8 percent are over 64. These numbers compare with statewide figures of 29.5 percent and 13.0 percent, respectively. La Paz County also presents a stark contrast to statewide averages for household income, with 48.2 percent (4,044) of its 8,392 households earning less than $25,000, compared to the statewide average of 28.9 percent. In addition, of the 8,362 occupied housing units in La Paz County only 21.9 percent (1,834) are renter occupied, yielding a homeownership-to-renter ratio of 3.6 to 1.0. As shown in Table 4-32 this figure compares with the statewide average of 2.1 to 1.0. Contrasting with its relatively aged population, only 18.5 percent of La Paz County's 15,133 housing units were built prior to 1970, compared to a statewide average of 22.4 percent.

Table 4-31: La Paz County Populations Potentially Vulnerable to Hazards, 2000

	Population			Households	
Jurisdiction	**Total**	**<19 years**	**65+ years**	**Total**	**Income <$25,000**
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
La Paz County	19,715	4,539	5,088	8,392	4,044
As a % of County	100.0%	23.0%	25.8%	100.0%	48.2%
As a % of State	0.4%	0.3%	0.8%	0.4%	0.7%

Source: US Census Bureau.

Table 4-32: La Paz County Dwelling Units Potentially Vulnerable to Hazards, 2000

	Homeownership		Housing Units	
Jurisdiction	**Homeowners**	**Renters**	**Total**	**Built <1970**
Arizona	1,293,637	607,690	2,189,189	490,710
La Paz County	6,528	1,834	15,133	2,794

Source: US Census Bureau.

The 6,575 people representing the labor force of La Paz County are employed primarily in the tourism, agriculture, and retail trade sectors of the economy. With an unemployment rate of 5.2 percent, La Paz County has a slightly lower ratio of unemployed workers than the State as a whole (5.8 percent).

Currently, La Paz County is undertaking the process of updating the *La Paz County Comprehensive Plan*. This plan will evaluate the rural, unincorporated, non-tribal areas of the County, and is aimed at reflecting Arizona State's "Growing Smarter" legislation. The existing plan is being updated to reflect the rural-urban development issues in Coconino County. The residents of La Paz County are reviewing the draft of the updated comprehensive plan, and completion is expected sometime in 2004.

4.2.8 Maricopa County

Maricopa County is located in south-central Arizona and encompasses 9,226 square miles, 98 square miles of which are water. As shown Figure 4-11, Maricopa County is bisected by the Salt River, which runs northeast to southwest, and joins the Gila River near the center of the county. Several major roadways support both local and regional transportation needs in Maricopa County. Interstates 10, 17, and 8 all intersection in or near Phoenix, and provide access to surrounding states. Several other State and US Highways provide local and regional access throughout Arizona. Sky Harbor Airport, located in central Phoenix, is one of the busiest air travel facilities in the United States.

Federal and State government entities own 50 percent of Maricopa County land, including the U.S. Bureau of Land Management (28 percent), the U.S. Forest Service (11 percent), and the state of Arizona (11 percent). An additional 16 percent is publicly owned, and 5 percent is Indian reservation land. Arizona's warm climate and the year-round availability of recreational areas and parks have led to Maricopa County becoming a major tourism destination.

Today Maricopa County contains more than half of the Arizona's overall population. Growing 44.8 percent from 1990 to 2000, Maricopa County is expected to have 4.5 million residents by the year 2020, as shown in Table 4-33. If these growth trends continue Maricopa County's population will nearly double by the year 2040. Among the many significant communities in Maricopa County are Phoenix, Mesa, Glendale, Scottsdale, Chandler, Tempe, and Peoria. The dramatic growth projected for several of these communities is depicted through Table 4-33.

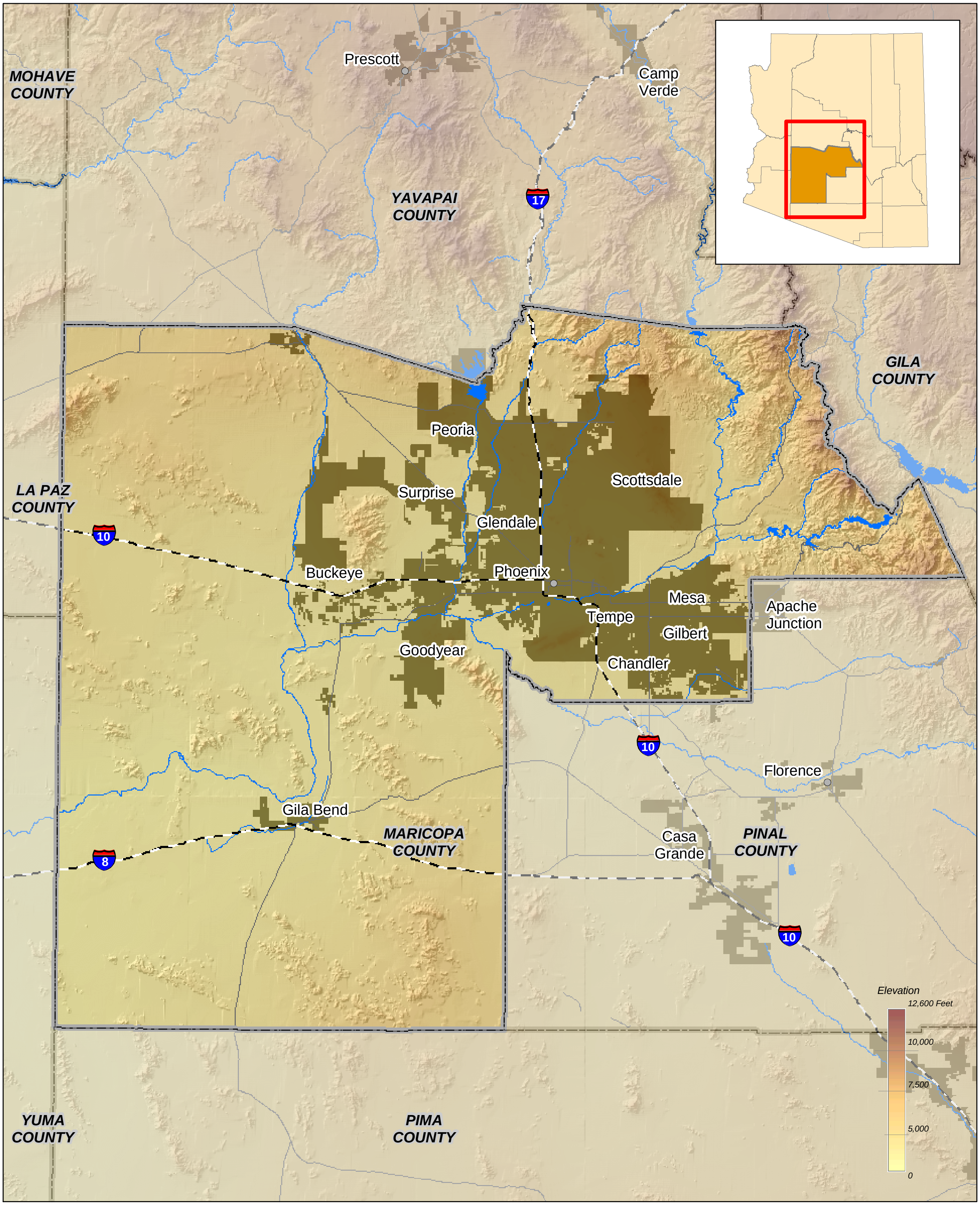
Table 4-33: Maricopa County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Maricopa County	2,122,101	3,072,149	3,296,250	3,709,566	4,516,090	5,390,785	6,296,219
Major Cities/Communities							
Chandler	90,533	176,581	194,390	221,664	258,915	285,067	305,265
Glendale	148,134	218,812	227,495	260,561	305,164	339,219	340,320
Mesa	288,091	396,375	427,550	540,608	593,962	635,668	652,461
Peoria	50,168	108,364	122,655	141,185	183,815	213,030	258,608
Phoenix	983,403	1,321,045	1,365,675	1,544,093	1,795,539	2,132,808	2,439,219
Scottsdale	130,069	202,705	214,090	270,763	306,713	356,656	374,032
Tempe	141,865	158,625	159,425	174,769	183,466	186,084	188,647

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997

As shown in Table 4-34, Maricopa County includes a large number but a modest proportion of population that is potentially vulnerable to hazards. Currently, over three million residents occupy Maricopa County, representing 60.2 percent of overall state population. Despite its image as a popular home for retirees, Maricopa County has a fairly youthful population base. The portion of its population both under the age of 19 (29.9 percent) and over the age of 64 (11.7 percent) almost parallel the statewide averages for these figures. Reflecting a more diverse and active economic base than its rural counterparts, 24.3 percent of Maricopa County households earn less than $25,000, compared to 28.9 percent for the state as a whole. In addition, of the 1,132,886 occupied housing units in Maricopa County only 32.5 percent (368,323) are renter occupied, yielding a homeownership-to-renter ratio of 2.1 to 1.0. Expectedly, this figure mirrors the statewide average of 2.1 to 1.0, as illustrated through Table 4-35. With a relatively new housing stock present in the rapidly growing suburban communities, 21.0 percent of Maricopa County's 1,250,231 housing units were constructed before 1970. This figure is slightly lower than the statewide average of 22.4 percent.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Figure 4-11

Major Features of Maricopa County

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Table 4-34: Maricopa County Populations Potentially Vulnerable to Hazards, 2000					
	Population			Households	
Jurisdiction	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Maricopa County	3,072,149	916,924	358,979	1,133,048	274,821
As a % of County	100.0%	29.9%	11.7%	100.0%	24.3%
As a % of State	59.9%	60.0%	53.8%	59.6%	50.1%
Source: US Census Bureau.					

Table 4-35: Maricopa County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		Housing Units	
Jurisdiction	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Maricopa County	764,563	368,323	1,250,231	262,325
Source: US Census Bureau.				

The metropolitan Phoenix area is the state's center of economic activity and is also home to a growing high-tech industry. The majority of workers in Maricopa County are employed in the services sector, followed by retails trades, government (U.S., State, and local), manufacturing, and finance/real estate/insurance. Major employers in Maricopa County include the State of Arizona, Maricopa County, the U.S. Postal Service, American Express, Arizona State University, Wal-Mart, and Wells Fargo Bank.

In the 1990's Maricopa County was the fastest growing county in the United States., gaining nearly 1 million new residents during this decade. Due to rapidly increasing development pressures and an appreciation for planning on a regional level, the County has committed to developing a development strategy that covers all of unincorporated Maricopa County. The *Maricopa County Comprehensive Plan*, now complete, compliments local development strategies that have been employed by all of the major communities in the greater Phoenix metropolitan area.

4.2.9 Mohave County

Covering 13,479 square miles Mohave County is the second largest county in the Arizona. Known mostly for its relationship with the Grand Canyon, a majority of Mohave County is occupied by desert. As shown in Figure 4-13, while water features cover only 1.4 percent of the County, over 1,000 miles of shoreline are created by the influence of the Colorado River and two man-made lakes—Lake Mohave and Lake Havasu. Several primary roadways influence Mohave County including Interstate 40, which links to Flagstaff to the east, and US Highway 93, connecting Phoenix with Las Vegas. A majority of land in Mojave County is publicly held, with various Federal and State entities owning over 75.0 percent of property in the County; Indian Reservations occupy 6.7 percent of Mohave County; and individuals or corporate interests occupy 17.2 percent of the County.

A county containing only a small portion of Arizona's overall population (3.0 percent), the rate of population growth in Mohave County greatly outpaces that of the state. As shown in Table 4-36, between 1990 and 2000, Mohave County's population increased 65.8 percent to reach 155,032 residents, while Arizona's population rose 40.0 percent during this time. Several moderately sized communities exist in Mohave County including Bullhead City, Kingman, New Kingman/Butler, Colorado City, and the largest community in the County—Lake Havasu City. Identified as ideal recreational locations along the Colorado River, the towns of Bullhead City, Lake Havasu City, and New Kingman/Butler, in particular, are projected to experience sizeable population gains in the coming decades.

Table 4-36: Mohave County Population, 1990-2040							
Jurisdiction	**1990**	**2000**	**2002**	**2010**	**2020**	**2030**	**2040**
Mohave County	93,497	155,032	166,465	194,403	236,396	270,785	295,045
Major Cities/Communities							
Bullhead City	21,951	33,769	35,410	41,899	53,848	62,434	67,597
Colorado City	2,426	3,334	3,905	5,500	6,626	7,598	8,321
Kingman	13,208	20,069	22,045	25,225	29,277	32,973	35,863
Lake Havasu City	24,363	41,938	46,400	58,777	68,886	78,550	86,399
New Kingman/Butler	N/A	14,810	15,900	23,127	29,248	33,821	36,721

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

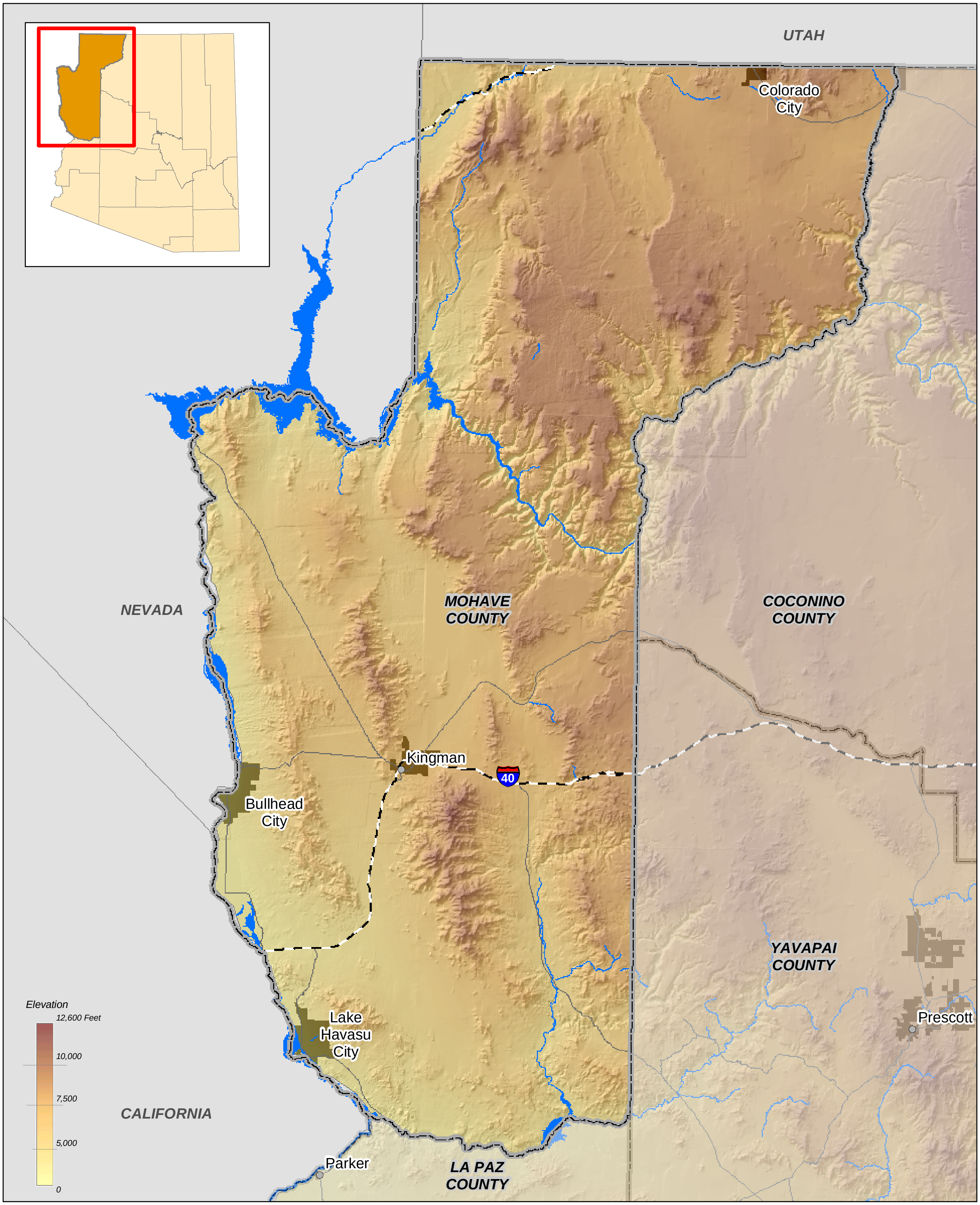
As shown in Table 4-37, Mohave County includes both a modest number and moderate proportion of population that is potentially vulnerable to hazards. With a relatively aged population base, only 25.4 percent of Mojave County residents are under 19 years of age, while 20.5 percent are over the age of 64. These figures compare to countywide totals of 29.5 percent and 13.0 percent, respectively. In addition, Mohave County's household income levels are substantially lower than the State average, with 38.4 percent of its 62,796 households earning less than $25,000, compared to 28.9 percent statewide. In addition, of the 62,809 occupied housing units in Mojave County only 26.4 percent (16,580) are renter occupied, yielding a homeownership-to-renter ratio of 2.8 to 1.0. As shown in Table 4-37, this figure compares with the statewide average of 2.1 to 1.0. Contrasting with its resident population, Mohave County's housing units are relatively young, with 10.7 percent of these structures being built prior to 1970, compared to 22.4 percent for Arizona as a whole.

Table 4-37: Mohave County Populations Potentially Vulnerable to Hazards, 2000					
	Population			**Households**	
Jurisdiction	**Total**	**<19 years**	**65+ years**	**Total**	**Income <$25,000**
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Mohave County	155,032	39,111	31,728	62,796	24,083
As a % of County	100.0%	25.2%	20.5%	100.0%	38.4%
As a % of State	3.0%	2.6%	4.8%	3.3%	4.4%

Source: US Census Bureau.

Table 4-38: Mohave County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		**Housing Units**	
Jurisdiction	**Homeowners**	**Renters**	**Total**	**Built <1970**
Arizona	1,293,637	607,690	2,189,189	490,710
Mohave County	46,229	16,580	80,062	8,544

Source: US Census Bureau.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

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- County Seat
- Highway
- Major Stream
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Figure 4-13

Major Features of Mohave County

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Of Mohave's 70,265 strong civilian labor force, 18.0 percent work in trade and 15.0 percent work in the service industries. A substantial share of the remaining jobs in Mojave County are contained in the government and construction sectors. In 2002 the unemployment rate in Maricopa County stood at 5.1 percent, which is slightly lower than the statewide average of 5.8 percent.

Although growing rapidly, Mojave County's comparatively basic development issues have not yet triggered the creation of a comprehensive land use development plan for the County. However, the Mojave County Planning and Zoning Department administers many land use development projects, and oversees other master planning projects including the Water Quality Management plan. Other recent planning initiatives include area plans for the I-40 corridor, the Golden Valley, and the Long Mountain areas.

4.2.10 Navajo County

Located in northeastern Arizona, Navajo County stretches from Arizona's northern border with Utah south to the central region of the State. As shown in

Figure 4-14, Navajo County is highlighted by several well-known natural features including the Mogollon Rim, the Petrified Forest National Park and the Painted Desert. The County is home to the Navajo Tribal Park at Monument Valley and several thriving Navajo and Hopi Indian communities. Almost 66 percent of Navajo County's 9,949 square miles is occupied by Indian reservation land. Several primary roadways influence Navajo County including Interstate 40, which links to Flagstaff to the west, and Arizona Highways 87 and 260, which connects Navajo County's mountain resort communities to Phoenix. Almost 66.0 percent of Navajo County is occupied by Indian Reservations; individual and corporate interests account for 18.0 percent; the U.S. Forest Service and Bureau of Land Management together control 9.0 percent; and the State of Arizona owns 5.9 percent.

Navajo County has only a small portion of Arizona's overall population (1.9 percent), the rate of population growth in Navajo County is somewhat less than that experienced statewide. As illustrated Table 4-39, between 1990 and 2000 Arizona's population increased 40.0 percent, while Navajo County grew at a slightly slower rate of 25.5 percent to reach a total of 97,470 residents. Several moderately sized mountain communities exist in the central and southern portions of Navajo County including Holbrook, Pinetop-Lakeside, Show Low, Snowflake, and the largest incorporated community in the County—Winslow. Constrained by rugged topography and distance to primary markets, most of the communities of Navajo County are not projected to grow substantially in the approaching decades. The towns of Winslow and Show Low, for example, are only expected to grow by 5,464 and 3,575 respectively, between 2002 and 2040.

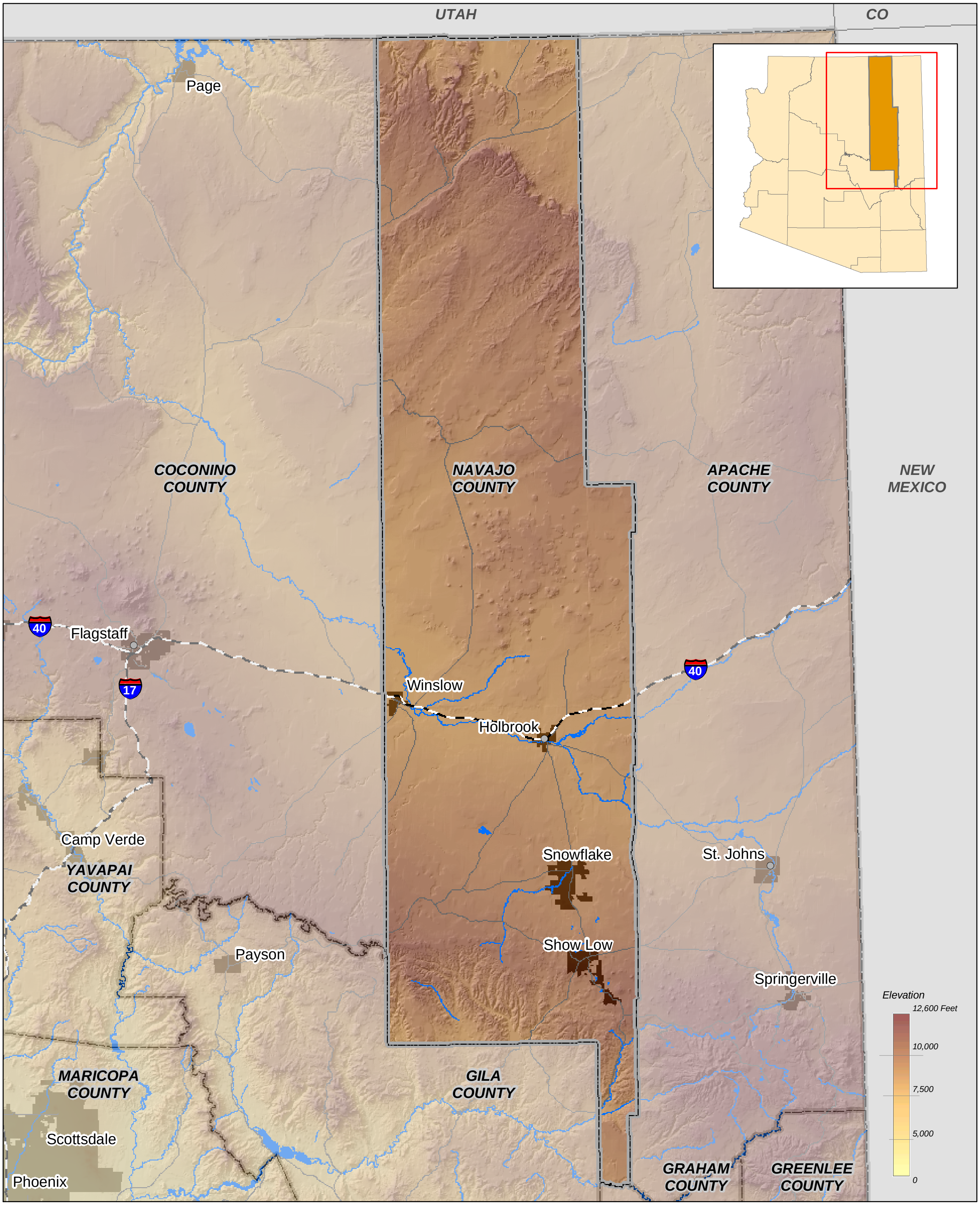
Table 4-39: Navajo County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Navajo County	77,658	97,470	101,615	99,979	111,946	123,460	134,323
Major Cities/Communities							
Fort Apache Indian Reservation (White Mtns.)	10,394	12,429	12,958	N/A	N/A	N/A	N/A
Holbrook	4,686	4,917	4,935	6,066	6,354	6,747	7,233
Hopi Indian Reservation	7,360	6,946	7,242	N/A	N/A	N/A	N/A
Kayenta, Navajo Nation	4,372	4,922	5,132	6,467	7,679	8,810	9,839
Pinetop-Lakeside	2,422	3,582	3,750	4,090	4,193	4,534	5,100
Show Low	5,019	7,695	8,295	8,823	9,742	10,765	11,870
Snowflake	3,679	4,460	4,700	4,888	5,143	5,513	5,987
Taylor	2,418	3,176	3,590	3,431	4,019	4,556	5,032
Winslow	8,190	9,520	9,450	12,249	13,007	13,994	14,914

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Navajo County has a relatively small number, but a high proportion of population that is potentially vulnerable to hazards. As shown in Table 4-40 Navajo County has a comparatively young population, with 38.5 percent of its residents less than 19 years of age, but only 10.0 percent over the age of 64. Additionally, Navajo County's household income levels are lower than those statewide, far exceeding the State of Arizona proportion of households that earn less than $25,000 (44.3 percent to 28.9 percent, respectively). In addition, of the 30,043 occupied housing units in Gila County only 24.5 percent (7,372) are renter occupied, yielding a homeownership-to-renter ratio of 3.1 to 1.0. Table 4-41indicates that this figure compares with the statewide average of 2.1 to 1.0. Expectedly, Navajo County's housing units are slightly aged, with 23.5 percent being built before 1970, compared to 22.4 percent for the State as a whole.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

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- County
- County Seat
- Highway
- Major Stream
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Figure 4-14

Major Features of Navajo County

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Table 4-40: Navajo County Populations Potentially Vulnerable to Hazards, 2000					
	Population			Households	
Jurisdiction	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Navajo County	97,470	37,557	9,758	30,055	13,313
As a % of County	100.0%	38.5%	10.0%	100.0%	44.3%
As a % of State	1.9%	2.5%	1.5%	1.6%	2.4%

Source: US Census Bureau.

Table 4-41: Navajo County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		Housing Units	
Jurisdiction	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Navajo County	22,671	7,372	47,413	11,157

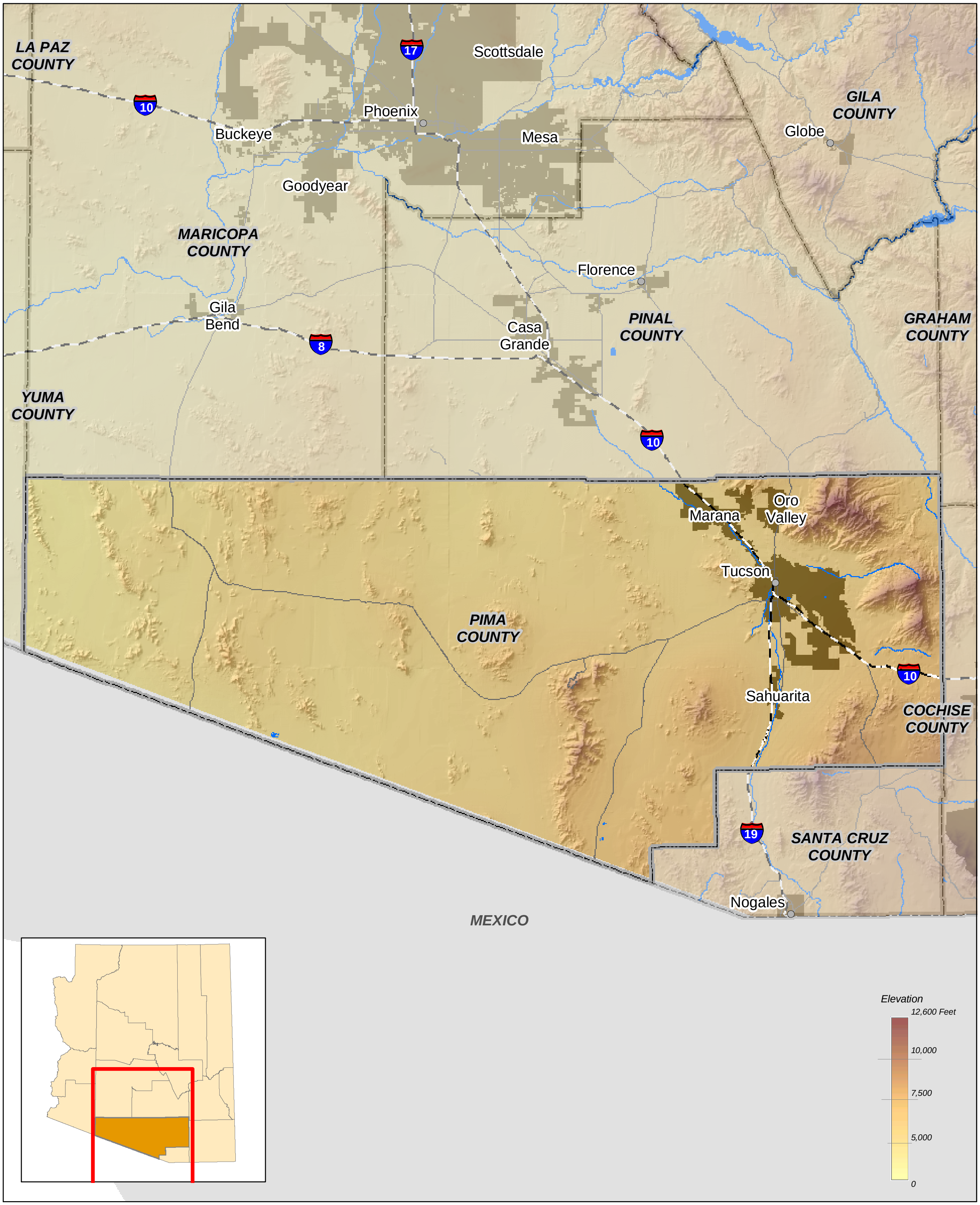
Source: US Census Bureau.

Today, Navajo County's principal industries include tourism, coal mining, manufacturing, timber production and ranching. Federal, State, or local government entities employ one third of the civilian labor force. The unemployment rate in 2002 was 10.2 percent. Compared to the statewide average of 5.2 percent, Navajo County's unemployment rate is nearly double that experienced throughout the State.

Navajo County's slow rate of growth countywide is reflective of the overall development climate in the region, which promotes preservation of critical natural resources and focuses on controlled growth in and around existing communities. Navajo County is currently drafting a *comprehensive plan* that will identify appropriate areas for new development and will support the preservation of vital natural amenities. County officials anticipate completion of this document in 2004.

4.2.11 Pima County

Pima County is one of the southernmost counties in Arizona, bordering Mexico and Santa Cruz County to the south. As shown in Figure 4-15, Pima County covers 9,184 square miles, and contains many parks including Tortolita Mountain Park, Tucson Mountain Park, Colossal Cave Mountain Park, Cienega Creek Natural Preserve, and Agua Caliente Park, as well as Saguaro National Park and Organ Pipe National Monument. Several primary roadways influence Pima County including Interstates 10 and 19, which provide access to El Paso and Nogales, respectively, and Arizona State Highways 85 and 86. The of State of Arizona owns 14.9 percent of the land in Pima County, and the U.S. Forest Service and Bureau of Land Management owns 12.1 percent. There are three reservations in Pima County; the San Xavier, Pascua Yaqui, and Tohono O'odham, which account for ownership of 42.0 percent of the land.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

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Figure 4-15

Major Features of Pima County

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As shown in Table 4-42, Pima County contains a relatively large portion of Arizona's overall population (16.5 percent) when compared to many other counties in Arizona. Despite this proportion, and the presence of Arizona's second-largest city—Tucson, Pima County has experienced a rate of population growth that is somewhat less than that experienced statewide. Between 1990 and 2000 Arizona's population increased 40.0 percent while Pima County grew at a rate of only 26.5 percent to arrive at a total population of 843,746. In addition to Tucson other major communities in the County include: Green Valley, Oro Valley, South Tucson, Marana, and Catalina. The communities of Tucson, Marana, and Oro Valley, among others, are expected to experience substantial population gains in the approaching decades.

Table 4-42: Pima County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Pima County	666,880	843,746	890,545	1,031,623	1,206,244	1,372,319	1,522,615
Major Cities/ Communities							
Catalina	4,864	7,025	7,414	N/A	N/A	N/A	N/A
Green Valley	20,644	17,283	18,241	N/A	N/A	N/A	N/A
Marana	2,187	13,556	17,770	46,078	76,553	99,328	117,900
Oro Valley	6,670	29,700	34,050	44,190	59,388	68,914	76,123
South Tucson	5,093	5,490	5,520	6,474	7,151	7,500	7,500
Tohono O'odam	18,730	13,586	13,890	N/A	N/A	N/A	N/A
Tucson	405,390	486,699	507,085	540,307	589,899	631,889	663,542

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Pima County includes a relatively high number but a balanced proportion of population that is potentially vulnerable to hazards, as illustrated through Table 4-43. Appropriately, the proportion of residents in Pima County falling below 19 years of age approximates the statewide average (28.0 percent to 29.5 percent), as does the relationship of those residents above the age of 64 (14.2 percent to 13.0 percent). Contrasted with the other large population center in Arizona—Maricopa County—Pima County exceeds the statewide average for the number of households that earn less than $25,000 (32.9 percent to 28.9 percent). In addition, of the 332,350 occupied housing units in Pima County 35.7 percent (118,730) are renter occupied, yielding a homeownership-to-renter ratio of 1.8 to 1.0. As shown in Table 4-44, this figure compares with the statewide average of 2.1 to 1.0. The strong history of the Tucson area justifies a housing stock that has a relatively high proportion of units that were constructed prior to 1970 when compared to the statewide average (28.8 percent to 22.4 percent, respectively).

Table 4-43: Pima County Populations Potentially Vulnerable to Hazards, 2000

	Population			Households	
Jurisdiction	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Pima County	843,746	235,880	119,487	332,497	109,254
As a % of County	100.0%	28.0%	14.2%	100.0%	32.9%
As a % of State	16.5%	15.5%	17.9%	17.5%	19.9%

Source: US Census Bureau.

Table 4-44: Pima County Dwelling Units Potentially Vulnerable to Hazards, 2000				
Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Pima County	213,620	118,730	366,737	105,610
Source: US Census Bureau.				

A majority of workers in Pima County are employed in the services sector of the economy, followed by government, retail trades, manufacturing, and construction. In 2002 the unemployment rate in Pima County was 4.5 percent, compared to the statewide average of 5.2 percent.

The Pima County Comprehensive Plan was adopted by the Board of Supervisors on October 13, 1992. A major Plan Update was adopted on December 18, 2001. A major focus of the Comprehensive Plan is the identification of measures to promote managed growth in the County's unincorporated areas near the active growth communities of Pima County. County leaders hope that, by encouraging managed growth, balanced communities will develop in a way that also preserves the region's natural resources.

4.2.12 Pinal County

Forming a sort of "bridge" between the growing areas of Maricopa County to the north and Pima County to the south, Pinal County is located in the central portion of Arizona, as shown in Figure 4-16. Formed from portions of Pima and Maricopa counties in 1875, today Pinal County encompasses 5,371 square miles, only 30 square miles of which are comprised of water. Pinal County is known for its natural and economic diversity, with the eastern portion of the County characterized by mountains, while roughly the western half of the County includes massive farming and ranching areas. Florence, established in 1866, has remained the county seat since its incorporation. Several primary roadways influence Pinal County including Interstate 10, which provides access to Phoenix and Tucson, and Interstate 8, which links Arizona to San Diego. The of State of Arizona owns 35.3 percent of the land in Pinal County, private interests occupy 26.0 percent, and the U.S. Forest Service and Bureau of Land Management owns 17.5 percent. There are no significant Native American land interests in Pima County.

As shown in Table 4-45, Pinal County contains a relatively small portion of Arizona's overall population (3.5 percent). Despite this small proportion, Pinal County has experienced a rate of population growth that is somewhat greater than that experienced statewide. Between 1990 and 2000 Arizona's population increased 40.0 percent while Pinal County grew 54.4 percent to reach a total resident population of 179,727 residents. Table 4-45 also indicates significant community growth areas in the County that include: Apache Junction, Arizona City, Casa Grande, Coolidge, Eloy, Florence, Oracle, and San Miguel. Reflecting a County population growth rate that is comparatively greater than the state average, the communities located near the Pinal County's western border with Maricopa County, including Apache Junction, Florence, and currently unincorporated Pinal County, are expected to experience massive population increases in the approaching decades.

Pinal County, located between the population centers of Phoenix and Tucson in central Arizona, has a relatively moderate number, but a high proportion of population that is potentially vulnerable to hazards, as shown in Table 4-46. The County has a slightly aged resident base, with 27.7 percent of its citizens less than 19 years of age and 16.2 percent over the age of 65. These numbers compare with statewide totals of 29.5 percent and 13.0 percent, respectively. Pinal County's percentage of low-income earners exceeds the statewide average, with 33.2 percent of its households earning incomes under $25,000, compared to 28.9 percent for Arizona. In addition, of the 61,364 occupied housing units in Gila County only 22.6 percent (13,842) are renter occupied, yielding a homeownership-to-renter ratio of 3.4 to 1.0. As shown in Table 4-47, this figure compares with the statewide average of 2.1 to 1.0. Reflecting new growth influences from the greater Phoenix metropolitan area, Pinal County's housing units are comparatively new, with 19.5 percent being built before 1970, compared to 22.4 percent for the State as a whole.

Table 4-45: Pinal County Population, 1990-2040							
Jurisdiction	**1990**	**2000**	**2002**	**2010**	**2020**	**2030**	**2040**
Pinal County	116,379	179,727	192,395	199,715	231,229	255,695	273,057
Major Cities/Communities							
Ak-Chin Indian Community	446	669	716	N/A	N/A	N/A	N/A
Apache Junction	18,100	31,814	33,570	25,957	28,718	30,861	32,382
Casa Grande	19,082	25,224	27,830	25,751	28,275	30,325	31,625
Coolidge	6,927	7,786	8,160	7,551	7,784	7,965	8,094
Eloy	7,211	10,375	10,810	10,651	11,562	12,269	12,770
Florence	7,321	17,054	14,540	12,240	12,637	12,945	13,164
Gila River Indian Community	9,540	11,257	12,050	N/A	N/A	N/A	N/A
Kearny	2,262	2,249	2,255	2,903	3,146	3,334	3,468
Oracle	3,043	3,563	3,814	6,402	7,637	8,596	9,277
San Manuel	4,009	4,375	4,683	4,605	4,782	4,919	5,016
Superior	3,468	3,254	3,280	3,568	3,616	3,652	3,678

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

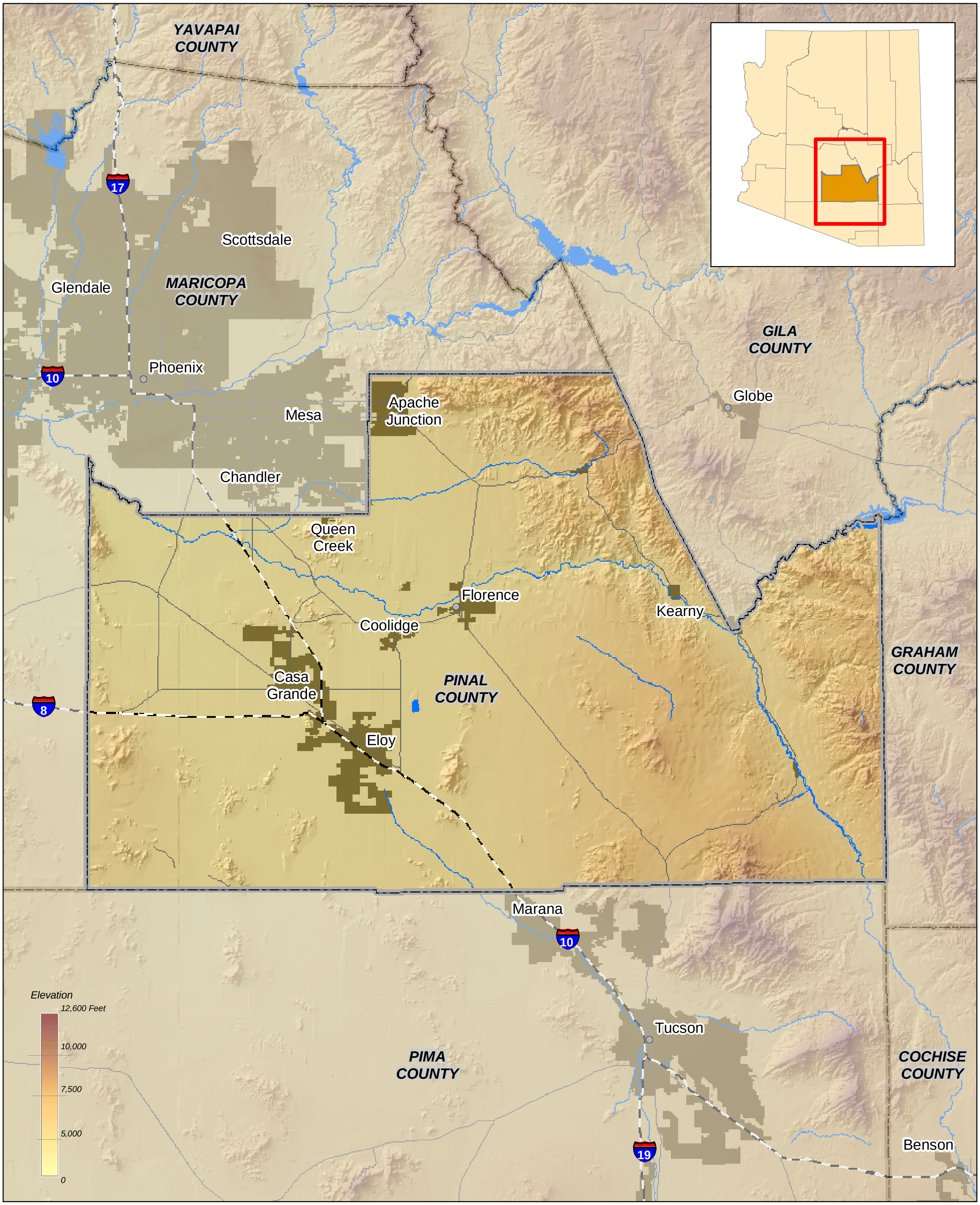
Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Table 4-46: Pinal County Populations Potentially Vulnerable to Hazards, 2000					
	Population			**Households**	
Jurisdiction	**Total**	**<19 years**	**65+ years**	**Total**	**Income <$25,000**
Arizona	5,130,632	1,527,188	667,839	1,901,625	5,130,632
Pinal County	179,727	49,742	29,171	61,413	20,411
As a % of County	100.0%	27.7%	16.2%	100.0%	33.2%
As a % of State	3.5%	3.3%	4.4%	3.2%	3.5%

Source: US Census Bureau.

Table 4-47: Pinal County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		**Housing Units**	
Jurisdiction	**Homeowners**	**Renters**	**Total**	**Built <1970**
Arizona	1,293,637	607,690	2,189,189	490,710
Pinal County	47,522	13,842	81,154	15,790

Source: US Census Bureau.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

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- City
- County
- County Seat
- Highway
- Major Stream
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Figure 4-16

Major Features of Pinal County

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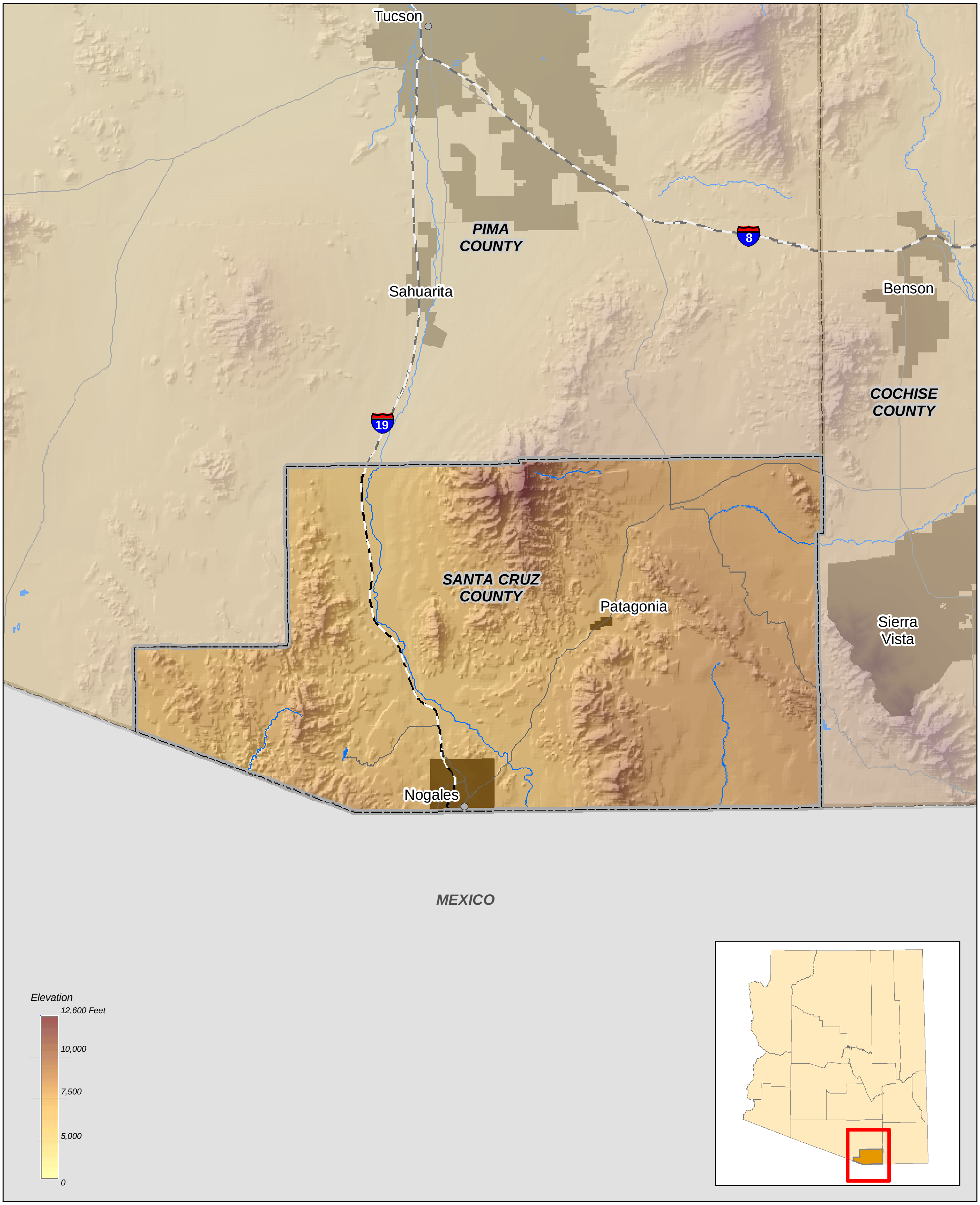
Services, trade, manufacturing and agricultural industries encompass the major industries of the Pinal County workforce, with government positions occupying the greatest number of positions in the county. The 63,867 employees comprising the Pinal County civilian labor force in 2002 experienced an unemployment rate of 7.3 percent, which is higher than the state's overall unemployment rate of 5.8 percent.

In 2001 the Pinal County Board of Supervisors approved an update of the County's *Comprehensive Land Use Plan*. A major focus of the Comprehensive Plan is the identification of measures to promote managed growth in the County's unincorporated areas, especially those affected by the active development influences of Maricopa County. County leaders hope that, by encouraging balanced growth opportunities in appropriate locations, healthy communities will develop in a way that also preserves the region's valuable natural resources.

4.2.13 Santa Cruz County

Santa Cruz County, the smallest county in Arizona, is located in the southern part of the state and covers 1,236 square miles. The county is named after the river that flows into Mexico from Arizona before winding back into Santa Cruz and Pima counties. As shown in Figure 4-17, Nogales is the county seat and there are strong commercial, religious and cultural ties between Nogales, Arizona and its sister city across the border, Nogales, Sonora. The town of Tubac is recognized as Arizona's first European settlement and is home to Arizona's first state park – Tubac Presidio State Historic Park. The only noteworthy roadway that influences Santa Cruz County is Interstate 19, which provides access between Tucson to the north and Nogales, Mexico to the south. The U.S. Forest Service and Bureau of Land Management own 54.6 percent of the land in Santa Cruz County, the State of Arizona owns 7.8 percent, and private interests own 37.5 percent. There are no significant Native American land interests in Santa Cruz County.

As shown in Table 4-48, the 2002 population of Santa Cruz County was 39,840. The County grew its resident population at a rate of 29.3 percent between 1990 and 2000, which is somewhat less than the State's overall growth of 40.0 percent during the same period. The towns of Nogales, Patagonia, Rio Rico, and unincorporated Tubac are the only communities in the County. Population estimates and projections for these communities are also provided through Table 4-48. Nogales is the county seat and also includes the highest population in Santa Cruz County. All of the communities in the County are expected to grow moderately, with Nogales being the only community to show substantial population gains in the coming decades.



Source: HAZUS 99; ALRIS July 2001; URS October 2003

LEGEND

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Figure 4-17

Major Features of Santa Cruz County

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Table 4-48: Santa Cruz County Population, 1990-2040							
Jurisdiction	**1990**	**2000**	**2002**	**2010**	**2020**	**2030**	**2040**
Santa Cruz County	29,676	38,381	39,840	46,246	55,111	64,459	73,892
Major Cities/Communities							
Nogales	19,489	20,878	21,110	24,282	27,782	31,059	33,929
Patagonia	888	881	905	1,022	1,033	1,071	1,138
Rio Rico	1,407	1,413	1,809	2,083	2,463	2,856	3,243
Tubac	902	949	985	N/A	N/A	N/A	N/A
Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).							
Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.							

Santa Cruz has a very small number but modest proportion of population that is potentially vulnerable to hazards, as shown in Table 4-49. Santa Cruz County has a relatively young resident base with 36.5 percent of its population less than 19 years of age, but only 10.7 percent over 64. These numbers contrast with statewide totals of 29.5 percent and 13.0 percent, respectively. Santa Cruz County's percentage of low household income levels, however, are dramatically higher than those statewide, with 41.7 percent of the 11,821 households earning less than $25,000, compared to 28.9 percent statewide. In addition, of the 11,809 occupied housing units in Gila County only 32.0 percent (3,781) are renter occupied, yielding a homeownership-to-renter ratio of 2.1 to 1.0. As shown in Table 4-50, this figure mirrors the statewide average of 2.1 to 1.0. Santa Cruz County's 13,036 housing units reflect construction age that is comparatively higher than the statewide average, with 28.8 percent being built before 1970, compared to 22.4 percent statewide.

Table 4-49: Santa Cruz County Populations Potentially Vulnerable to Hazards, 2000					
	Population			**Households**	
Jurisdiction	**Total**	**<19 years**	**65+ years**	**Total**	**Income <$25,000**
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Santa Cruz County	38,381	14,006	4,114	11,821	4,931
As a % of County	100.0%	36.5%	10.7%	100.0%	41.7%
As a % of State	0.8%	0.9%	0.6%	0.6%	0.9%
Source: US Census Bureau.					

Table 4-50: Santa Cruz County Dwelling Units Potentially Vulnerable to Hazards, 2000				
	Homeownership		**Housing Units**	
Jurisdiction	**Homeowners**	**Renters**	**Total**	**Built <1970**
Arizona	1,293,637	607,690	2,189,189	490,710
Santa Cruz County	3,781	8,028	13,036	3,760
Source: US Census Bureau.				

Transportation, service industries, manufacturing, government sectors encompass the major industries of the Santa Cruz County workforce, with retail trade positions occupying the greatest number of positions in the County. The

13,862 employees comprising the Pinal County civilian labor force in 2002 experienced an unemployment rate of 12.8 percent, which is substantially higher than the state's overall unemployment rate of 5.8 percent.

In 2001 the Santa Cruz County Board of Supervisors approved an update of the *County's Comprehensive Land Use Plan*. This Plan, which is administered by the Santa Cruz County Community Development Department, identifies measures to promote balanced land use growth in the County's unincorporated areas, especially those affected by the active development influences created by Nogales.

4.2.14 Yavapai County

Located in the center of the State, Yavapai County was once called the "Mother of Counties" because it included land now part of Apache, Coconino, Gila, Maricopa, and Navaho counties in Arizona. Today, Yavapai County covers 8,123 square miles. As shown in Figure 4-18, Prescott is Yavapai's county seat. Several roadways provide access throughout the mountainous territory of Yavapai County including Interstates 40 and 17, Arizona Highway 69, and U.S. Highways 93 and 89. The U.S. Forest Service owns 38.0 percent of Yavapai land, including portions of Prescott, Tonto, and Coconino national forests. The State of Arizona owns and additional 24.6 percent, 25.0 percent is individually or corporately owned, and the U.S. Bureau of Land Management owns 11.6 percent. The Yavapai Indian Reservation and other public lands make up less than 0.5 percent of the County.

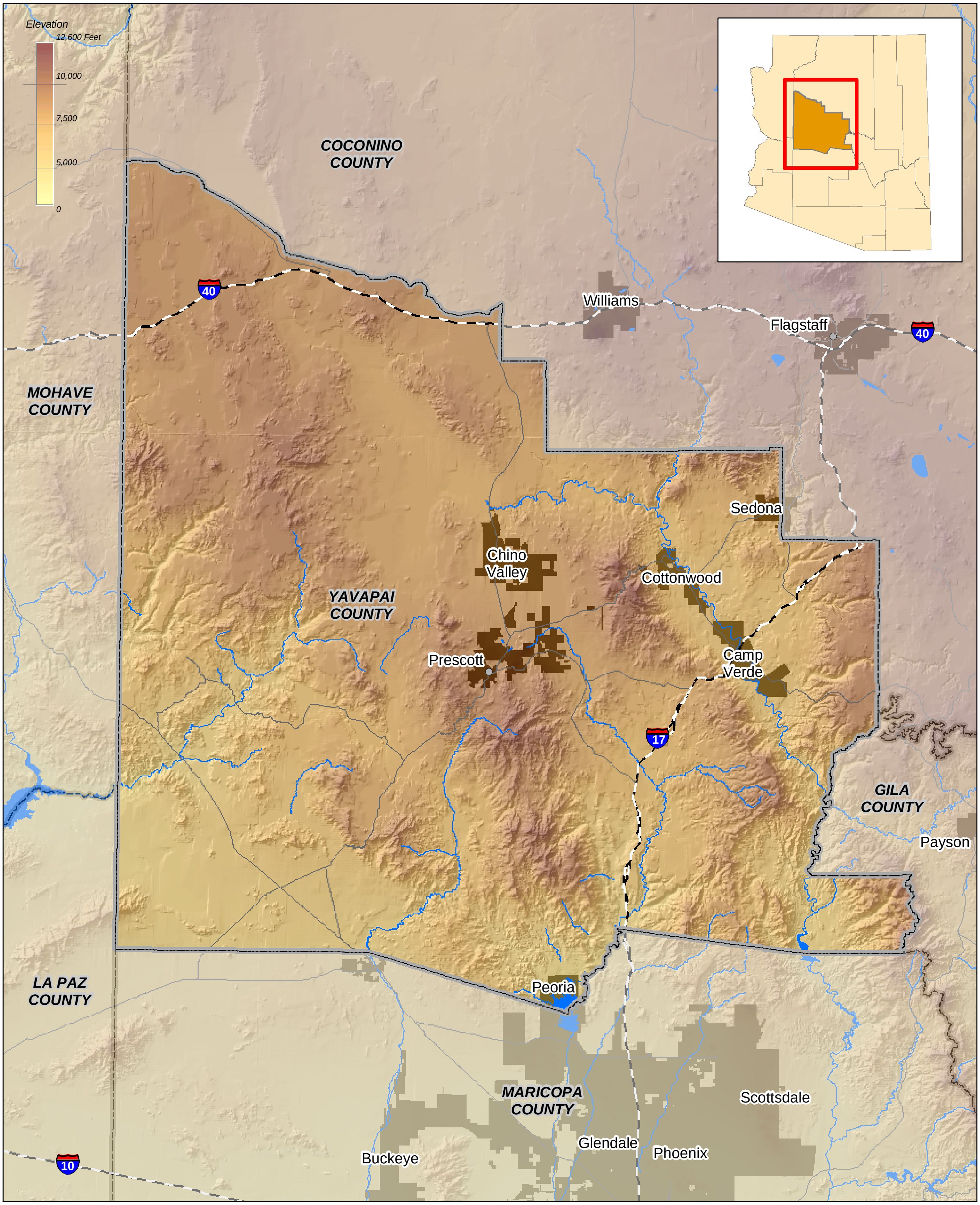
Yavapai County represents one of the fastest growing populations in Arizona. Between 1990 and 2000, the County's population grew by a remarkable 145.8 percent. As shown in Table 4-51, the 2002 population of Yavapai County was 180,260. The Towns of Camp Verde, Chino Valley, Cottonwood, Prescott, Prescott Valley, and Sedona comprise the bulk of Yavapai County's population. All of the communities in the County are expected to continue to grow moderately, with Prescott and Prescott Valley projected to post especially high population gains in the coming decades.

Table 4-51: Yavapai County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Yavapai County	68,145	167,517	180,260	198,052	240,849	278,426	305,681
Major Cities/Communities							
Bagdad	1,858	1,578	1,698	1,866	1,870	1,874	1,877
Camp Verde	6,243	9,451	9,940	11,407	14,068	16,318	17,884
Chino Valley	4,837	7,835	8,205	10,445	12,771	14,928	16,580
Clarkdale	2,144	3,422	3,570	3,932	4,786	5,531	6,067
Cottonwood	5,918	9,179	10,020	10,749	15,246	19,053	21,706
Jerome	403	329	330	686	772	847	901
Prescott	26,592	33,938	36,375	42,272	49,863	56,472	61,222
Prescott Valley	8,858	23,535	26,115	35,776	46,365	56,427	64,307
Sedona (Coconino & Yavapai)	7,720	10,192	10,540	12,380	14,611	16,546	18,088
Verde Village	7,000	10,610	11,417	N/A	N/A	N/A	N/A

Note: Figures for 1990, 2000, 2002 from Arizona Dept. of Commerce. Figures for 2010-2040 from AZ DES (projections date from 1997).

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.



Source: HAZUS 99; ALRIS July 2001; October 2003

LEGEND

Interstate

City

County

County Seat

Highway

Major Stream

Lake

N

0 5 10 20

Miles

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 4-18

Major Features of Yavapai County

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Yavapai County has a comparatively small number but modest proportion of population that is potentially vulnerable to hazards, as shown in Table 4-52. Yavapai County has a relatively aged resident base with only 23.5 percent of its citizens less than 19 years of age, but 22.0 percent over the age of 64. These numbers contrast with statewide totals of 29.5 percent and 13.0 percent, respectively. Yavapai County's ratio of very low household incomes is substantially higher than the State average, with 34.3 percent of its 70,069 households earning less than $25,000, compared to 28.9 percent statewide. In addition, of the 70,171 occupied housing units in Yavapai County only 26.6 percent (18,652) are renter occupied, yielding a homeownership-to-renter ratio of 2.8 to 1.0. As shown in Table 4-53, this figure compares with the statewide average of 2.1 to 1.0. Contrasting with its resident population, Yavapai County's housing units are comparatively young, with 17.2 percent being built prior to 1970, compared to 22.4 percent for the State.

Table 4-52: Yavapai County Populations Potentially Vulnerable to Hazards, 2000

Jurisdiction	Population			Households	
	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	5,130,632
Yavapai County	167,517	39,410	36,816	70,069	24,009
As a % of County	100.0%	23.5%	22.0%	100.0%	34.3%
As a % of State	3.3%	2.6%	5.5%	3.7%	3.3%

Source: US Census Bureau.

Table 4-53: Yavapai County Dwelling Units Potentially Vulnerable to Hazards, 2000

Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Yavapai County	51,519	18,652	81,730	14,095

Source: US Census Bureau.

The major industries in Yavapai include retail trade, services, and public administration. Of the 74,791 members of the labor force, 21.0 percent work in the services industry, 19.0 percent work in trade, and 14.0 percent work in federal and local government. The County enjoys a relatively low unemployment rate of 3.5 percent, which stands in comparison to the statewide average of 5.8 percent.

The *Yavapai County General Plan*, adopted in 2003, acknowledges that the County faces challenges of balancing growth, development, and urbanization with open space preservation, water conservation, and protection of the traditional rural/ranching lifestyle. During the development of the General Plan, Yavapai citizens determined several land use goals, including: maintaining compatible land use patterns, sustaining the County's rural character, preserving open lands and the County's attractive image, and establishing public participation criteria for land use decisions.

4.2.15 Yuma County

Located in the farthest portion of southwestern Arizona Yuma County serves as the gateway to California. Yuma County was one of the original four counties designated by the First Territorial Legislature. Today, Yuma County spans 5,522 square miles, much of which is desert land accented by rugged mountains, as shown in Figure 4-19. Early in the region's development the City of Yuma became the region's primary railroad hub and has remained Yuma's County seat. Two primary roadways provide access throughout Yuma County and provide vital connections to Arizona and California: Interstate 8, which links Arizona with San Diego to the west, and US Highway 89, which provides access to the north. Public lands account for 81.6 percent of land ownership of which the U.S. Bureau of

Land Management controls 14.8 percent. Indian reservations account for 0.2 percent, the State of Arizona owns 7.7 percent, and individuals or corporate own 10.5 percent.

Yuma County represents one of the faster growing populations in Arizona. Between 1990 and 2000, the County's population grew 50.0 percent. As illustrated through Table 4-54, the 2002 population of Yavapai County was 169,760. The towns of San Luis, Somerton, and Wellton complement the City of Yuma, which is the predominant population, civic, and economic center of Yuma County. While most of the communities in Yuma County are expected to continue growing at a moderate pace, Yuma is projected to post an especially high population gain in the coming decades, will add 60,000 new residents to its current population of 81,380 by the year 2040.

Table 4-54: Yuma County Population, 1990-2040

Jurisdiction	1990	2000	2002	2010	2020	2030	2040
Yuma County	106,895	160,026	169,760	171,689	209,861	253,861	300,851
Major Cities/Communities							
Cocopah Indian Reservation	515	1,025	1,088	N/A	N/A	N/A	N/A
San Luis	4,212	15,322	18,345	16,976	20,517	26,595	35,311
Somerton	5,282	7,266	7,985	8,224	9,872	11,814	13,935
Wellton	1,066	1,829	1,870	1,415	1,610	1,841	2,094
Yuma	54,923	77,515	81,380	83,462	99,337	119,951	136,516

Source: Arizona Department of Commerce, May 2003; Arizona Department of Economic Security, February 1997.

Yuma County has a small number, but high ratio of population that is potentially vulnerable to hazards. With a total population of 160,026, Yuma County contains a modest proportion of the state's overall population base (3.1 percent). As illustrated in Table 4-55, Yuma County has a population that is proportionately both young and aged, with 31.9 percent (51,023) of its residents being less than 19 years of age and 16.5 percent (26,456) over the age of 64. These averages contrast with statewide figures of 29.5 percent and 13.0 percent, respectively. Together these age groups represent 48.4 percent of Yuma County's overall population. Yuma County's 53,904 households include 20,022 that earn less than $25,000 a year (37.1 percent). This number compares with the statewide average of 28.9 percent. Of the 53,848 occupied housing units in Yuma County only 27.8 percent (14,962) are renter occupied, yielding a homeownership-to-renter ratio of 2.6 to 1.0. As illustrated through Table 4-56, this figure compares with the statewide average of 2.1 to 1.0. In addition, Yuma County contains 74,140 housing units, 22.1 percent of which (16,399 units) were constructed prior to 1970—a comparison that nearly mirrors the statewide average of 22.4 percent.

Table 4-55: Yuma County Populations Potentially Vulnerable to Hazards, 2000

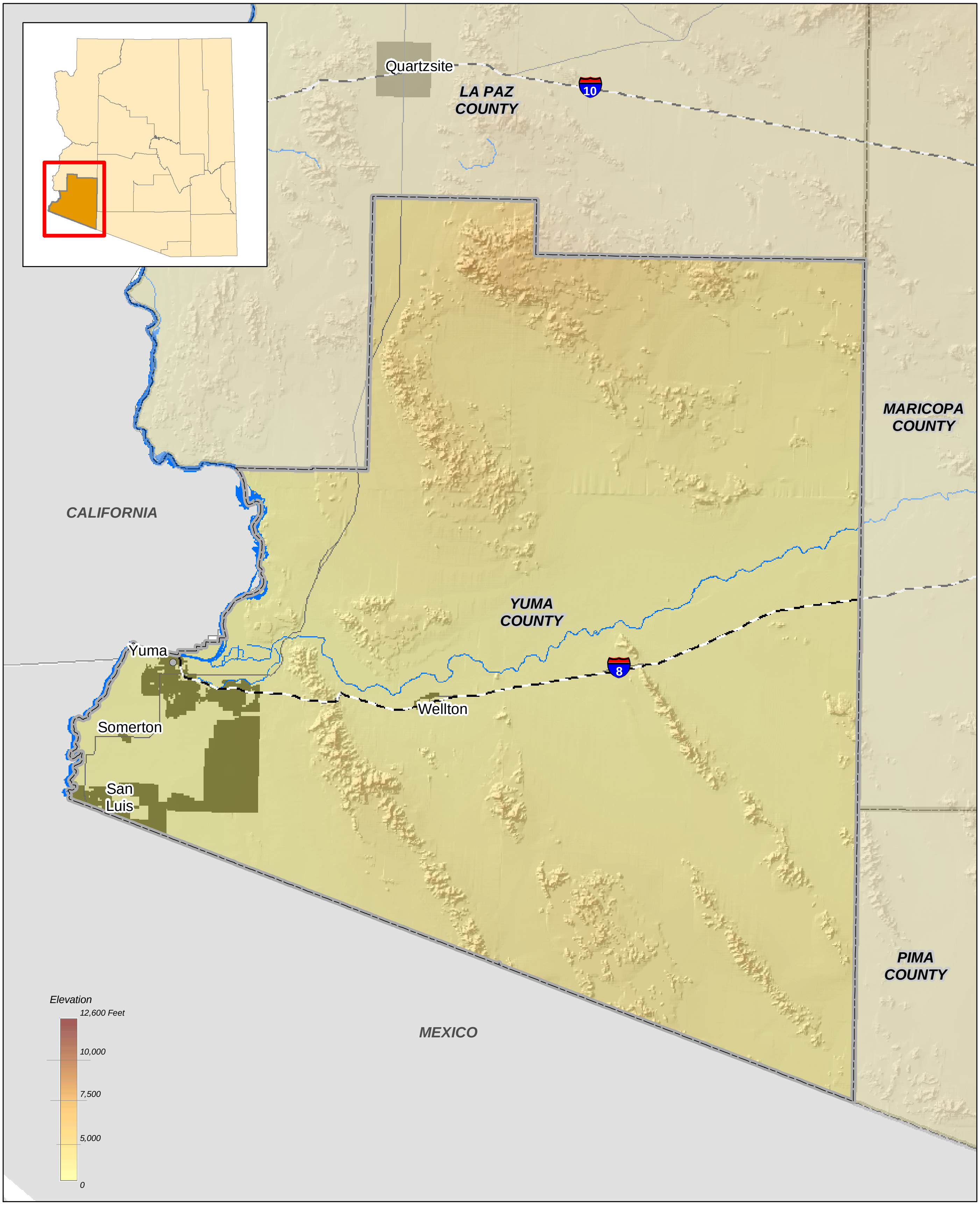
	Population			Households	
Jurisdiction	Total	<19 years	65+ years	Total	Income <$25,000
Arizona	5,130,632	1,527,188	667,839	1,901,625	548,383
Yuma County	160,026	51,023	26,456	53,904	20,022
As a % of County	100.0%	31.9%	16.5%	100.0%	37.1%
As a % of State	3.1%	3.3%	4.0%	2.8%	3.7%

Source: US Census Bureau.

Table 4-56: Yuma County Dwelling Units Potentially Vulnerable to Hazards, 2000				
Jurisdiction	Homeownership		Housing Units	
	Homeowners	Renters	Total	Built <1970
Arizona	1,293,637	607,690	2,189,189	490,710
Yuma County	38,886	14,962	74,140	16,399
Source: US Census Bureau.				

Agriculture, tourism, military, and government are the County's principal industries. The largest employment sector, agriculture, employs 13.4 percent of the population and 35.0 percent of the labor force. The unemployment rate in Yuma County stands at 23.0 percent, which indicates a very high number when compared to the statewide average (5.8 percent).

The Yuma County Comprehensive Plan, adopted in 2001, identifies the increasing number of winter visitors, tourists, military branches, and other government agencies as growth trends that threaten the County's agricultural and rural heritage. These growth pressures drive the conversion of farmland into rural home sites, commercial development, and recreational uses. Growth areas in the County have focused on existing urban centers—primarily in and around the City of Yuma, and the Cities of Wellton, Somerton, and San Luis.



Source: HAZUS 99; ALRIS July 2001; October 2003

LEGEND

- Interstate
- Highway
- City
- Major Stream
- County
- Lake
- County Seat

N

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Miles

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 4-19

Major Features of Yuma County

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7. RISK ASSESSMENT

The purpose of this section is to identify the hazards that can affect Arizona, profile the major hazards, assess the risk of such hazards, describe the vulnerability of the state's communities and State-owned, and estimate potential losses from the hazards. Each of these tasks is described in detail below. It is notable that this is the first time that a comprehensive effort of this kind has been undertaken in Arizona.

7.1 DMA 2000 Requirements and Approach

The requirements for the risk assessment according to *DMA 2000* are shown in Table 7-1. While technically only natural hazards must be addressed, most human-caused hazards are included in this plan in at least a preliminary manner. In order to meet these requirements, the State of Arizona used the step-wise approach to the risk assessment detailed in *Understanding Your Risks: Identifying Hazards and Estimating Losses* (FEMA 2001). This approach consists of the following major steps:

- Identify and screen hazards,
- Profile hazards,
- Inventory assets,
- Estimate losses,
- Future risks, and
- State-owned facilities.

Table 7-1: DMA 2000 Requirements – Risk Assessment			
Section	**Title**	**Requirement**	**Language**
Risk Assessment	Identifying Hazards	§201.4(c)(2)(i):	[The risk assessment shall include an] overview of the type … of all natural hazards that can affect the State…
Risk Assessment	Profiling Hazard Events	§201.4(c)(2)(i):	[The risk assessment shall include an] overview of the location of all natural hazards that can affect the State, including information on previous occurrences of hazard events as well as the probability of future hazard events, using maps where appropriate.
Risk Assessment	Assessing Vulnerability by Jurisdiction	§201.4(c)(2) (ii):	[The risk assessment shall include] an overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events…
Risk Assessment	Assessing Vulnerability of State Facilities	§201.4(c)(2) (ii):	[The risk assessment shall include an] overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in …the State risk assessment. …State owned critical or operated facilities located in the identified hazard areas shall also be addressed…
Risk Assessment	Estimating Potential Losses by Jurisdiction	§201.4(c)(2) (iii):	[The risk assessment shall include an] overview and analysis of potential losses to identified vulnerable structures, based on estimates provided in local risk assessments…
Risk Assessment	Estimating Potential Losses of State Facilities	§201.4(c)(2) (iii):	[The risk assessment shall include the following:]…[a]n overview and analysis of potential losses to identified vulnerable structures, based on estimates provided in …the State risk assessment. The State shall estimate the potential dollar losses to State-owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.
Source: FEMA, July 11, 2002.			

7.2 Identify and Screen Hazards

The first step in the risk assessment process is the identification and screening of hazards. Hazards identified include natural and human-caused hazards that might affect persons and property in Arizona. This includes hazards that have occurred in the past as well as those that may occur in the future (even if they have not yet occurred). Then the list of all possible hazards is screened to focus on the most likely or most damaging hazards.

To aid in identifying and screening hazards, a database of historical hazard events in Arizona was developed. Where possible, the information listed in Table 7-2 was recorded for each entry. In many cases, information on an event could not be found for particular fields, such as property damage. However, the database ultimately grew to approximately 1,450 entries, providing useful resources for the analysis of historical hazards in Arizona. It should be noted that reported information regarding fatalities, injuries, and property damage is available for only a small proportion of the total number of records and should, at best, be considered representative of the total damage caused by the hazard event.

Table 7-2: Arizona Historical Hazard Event Database Fields
Year
Event Date
Event Category
Event Sub-Category
City / Location Affected
Counties Affected
Disaster/Emergency Declared?
Declaration Type / No
State Declaration Date
Federal Declaration Date
Declaration Type
State Expenditures
Federal Expenditures
Fatalities
Injuries
Property Damage ($)
Crop / Livestock Damage ($)
Description
Source
Source: URS, October 2003.

The hazard event database was populated in step-wise manner. The first step was to review records from the Arizona Division of Emergency Management (ADEM), Federal Emergency Management Agency (FEMA), and United States Department of Agriculture (USDA), in order to identify and enter events that were declared a disaster or emergency by one or more of the following:

- Governor of Arizona;
- Secretary of the U.S. Department of Agriculture; or

- President of the United States.

Next, events were identified and entered that, while not declared a disaster or emergency, caused sufficient one-time or repetitive damage to be considered a hazard (other events). In order to limit the number of entries, the other events had to meeting one or more of following criteria:

- 1 or more fatalities,
- 1 or more injuries,
- $50,000 or more in damages, or
- significant event, as expressed in historical records or according to defined criteria.

The first three criteria are useful in order to screen the large number of hazard event records from the last 20-30 years. This includes records from such agencies as the Arizona State Land Department (ASLD), National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA), US Geological Survey (USGS), and US Forest Service (USFS). The last criteria enables the inclusion of historic hazard events that occurred prior to this time which often have relatively little specific information, but were considered significant enough to have gone into one or more historical records. Such entries were typically from narrative descriptions cited in a wide variety of sources that had been identified by the Arizona Division of Emergency Management (ADEM).

The hazard event database was used to conduct a preliminary evaluation of hazards in Arizona, as shown in Table 7-3. A decision was made by the State Hazard Mitigation Plan Team whether or not to profile the hazards in detail based on a number of factors, including the following:

- Prior knowledge of the relative risk presented by the hazards;
- Information from the hazard event database;
- The ability to mitigate the hazard via the *DMA2000* process; and
- The known or expected availability of information on the hazard.

Table 7-3: Historical Record of Hazards in Arizona by Type

Hazard	Historical Records						Further Evaluation As Major Hazard?
	Number of Records			Recorded Damages			
	Declarations	Other Events	Total	Fatalities	Injuries	Losses ($)	
Aviation Accident	1	24	25	25	0	$0	No
Civil Disturbance	4	1	5	0	0	$0	No
Dam Failure	2	4	6	150	0	$0	Yes
Disease	14	18	32	60	82	$145,408	Yes
Drought	17	93	110	0	0	$300,000,000	Yes
Dust Storm	0	11	11	11	103	$350,000	No
Earthquake	1	41	42	8	0	$0	Yes
Expansive Soil	0	0	0	0	0	$0	No
Extreme Cold	0	1	1	0	0	$0	No
Extreme Heat	0	11	11	0	0	$0	Yes
Fire	4	3	7	12	100	$1,000,000	No
Fissure	0	0	0	0	0	$0	No
Flood	40	63	103	35	250	$1,317,273,644	Yes
Fog	0	2	2	0	18	$0	No
Hail	0	13	13	0	6	$18,851,800	Yes
HAZMAT Event	8	73	81	1	24	$100,000,000	Yes
Landslide	1	0	1	0	0	$0	Yes
Lightning	0	48	48	9	68	$5,839,000	Yes
Meteor Strike	0	0	0	0	0	$0	No
Miscellaneous	4	0	4	0	0	$0	No
Mine Accident	0	5	5	31	0	$0	No
Nuclear Incident	0	0	0	0	0	$0	No
Prison Problem	5	0	5	0	0	$0	No
Public Safety	3	0	3	0	0	$0	No
Search and Rescue	3	1	4	0	0	$0	No
Service Interruption	5	1	6	0	0	$0	No
Severe Wind	0	5	5	1	0	$30,000	Yes
Subsidence	0	1	1	0	0	$3,000,000	Yes

Table 7-3: Historical Record of Hazards in Arizona by Type

Hazard	Historical Records: Number of Records			Historical Records: Recorded Damages			Further Evaluation As Major Hazard?
	Declarations	Other Events	Total	Fatalities	Injuries	Losses ($)	
Terrorism	2	0	2	0	0	$0	No
Thunderstorm	14	156	170	18	193	$430,188,500	Yes
Tornado	0	40	40	4	185	$42,930,000	Yes
Tropical Cyclone	4	9	13	38	975	$750,800,000	Yes
Volcano	0	0	0	0	0	$0	No
Wildfire	27	677	704	6	0	$34,340,000	Yes
Winter Storm	8	9	17	17	15	$2,150,000	Yes
Total	**167**	**1,310**	**1,477**	**426**	**2,019**	**$3,006,898,352**	

Note: Information on fatalities, injuries, and property damage is available for only a small proportion of the total number of records and should be considered indicative. Declarations refers to Presidential, USDA, or Gubernatorial declared disasters or emergencies. Events refer to undeclared events with 1 or more fatalities, 1 or more injuries, $50,000 or more in damages, or historically significant event (as expressed in historical records). The hazard event database covers the period 1830 to 2002, although approximately 90 percent of the records are from 1970 or more recently. Long-term hazard events, such as droughts, were entered for each reported year of occurrence.

Source: URS, October 2003.

7.3 Hazard Profiles

The hazards selected for profiling were examined in a methodical manner based on the following four factors, with each factor considered in detail for the hazards profiled:

- **Nature**: This topic provides basic information about the hazard that is sufficient to enable a user of the plan to comprehend its nature and distinguish it from other hazards. It also provides a basis for leaders to understand the subsequent vulnerability assessment and loss estimates. The information for this section is drawn mainly from FEMA and other national agencies.
- **History**: Background information about previous occurrences of the hazard is provided. The focus is on disasters and other events that have occurred in Arizona and, where Arizona information is lacking, on major occurrences elsewhere in the United States. The information in this section is drawn mainly from the database of historical hazard events in Arizona.
- **Probability and Magnitude**: As the title indicates, the focus of this topic is the probability or frequency of the hazard in Arizona as well its magnitude. The information in this section is drawn from a combination of FEMA and other national sources, Arizona expertise, and the Arizona hazard event database. Where possible, the focus of this section is on a commonly accepted design event.
- **Warning Time**: This topic provides information on the amount of time available for preparation prior to the occurrence of the design event. The information in this section is drawn from a combination of FEMA and other national sources, Arizona expertise, and the Arizona hazard event database.

In an effort to provide as much information as possible about each hazard, extensive text analysis as well as associated tables and graphics have been included for each of the hazard profiles below. These hazards profiles should be considered introductory, with additional and more detailed analysis available via the many sources cited below.

7.3.1 Dam Failure

7.3.1.1 Nature

A dam is a barrier constructed across a watercourse in order to store, control, or divert water, which is usually constructed of earth, rock, concrete, or mine tailings. The water impounded behind a dam is referred to as the reservoir and is measured in acre-feet, with one acre-foot being the volume of water that covers one acre of land to a depth of one foot. Due to topography, even a small dam may have a reservoir containing many acre-feet of water. A dam failure is the collapse, breach, or other failure of a dam that causes downstream flooding. Dam failures may result from natural events, human-caused events, or a combination thereof. Due to the lack of advance warning, failures from natural events, such as hurricanes, earthquakes, or landslides, may be particularly severe. Prolonged rainfall that produces flooding is the most common cause of dam failure (FEMA,1997).

Dam failures usually occur when the spillway capacity is inadequate and water overtops the dam or when internal erosion through the dam foundation occurs (also known as piping). If internal erosion or overtopping cause a full structural breach, a high-velocity, debris-laden wall of water is released and rushes downstream, damaging or destroying whatever is in its path. Dam failures may result from one or more the following:

- Prolonged periods of rainfall and flooding (the cause of most failures);
- Inadequate spillway capacity which causes excess overtopping flows;
- Internal erosion erosions due to embankment or foundation leakage or piping;
- Improper maintenance;
- Improper design;
- Negligent operation;

- Failure of upstream dams;
- Landslides into reservoirs;
- High winds; and
- Earthquakes.

7.3.1.2 History

The deadliest dam failure in U.S. history was in Johnstown, Pennsylvania, in 1889 when more than 2,209 people died. The June 5, 1976 failure of the Teton Dam in Idaho killed 11 people and caused approximately $1.0 billion in damages (FEMA, 1997).

In Arizona, two dam failure declarations (Presidential or Gubernatorial disaster or emergency declaration) and four additional undeclared dam failure events were identified in Arizona, as shown in Table 7-3. These resulted in an estimated 150 fatalities. These events included the following:

- The Walnut Grove Dam failure on February 22, 1890, was the most significant dam failure experienced in the state. The dam failed due to overtopping and the ensuing flood caused an estimated 150 deaths and extensive destruction of property. The failure was blamed on inadequate capacity of the spillway and poor construction (Arizona Division of Emergency Management, March 1998). Located 30 miles by river north of Wickenburg on the Hassayampa River, the dam was built to provide water for irrigation and gold placer mining. The rock fill structure was 110 feet high, 400 feet long, had a base width of 140 feet, a top width of 10 feet, and a spillway of 5 feet deep by 20 feet long. The lake was 2.5 miles long by 0.75-1.0 mile wide covering over 1,100 acres, and an average depth of 60 feet.

  Based upon various accounts of the Walnut Grove Dam failure, the weather at the time was rain and melting snow. The day before the breach, water in the lake rose rapidly at the rate of about one and one-half foot per hour. The spillway was enlarged to allow excess water to escape but the effort was insufficient to stop water from running over the top. A sheet of water three feet thick reportedly poured over the dam top for six hours. Between 1:00 and 2:00 am on Saturday, February 22, 1890 the dam broke and the lake drained in one to two hours. The water rushed down Box Canyon, a narrow, steep canyon in a body 80 feet high. The floodwaters reached the town of Wickenburg, 30 miles downstream in two hours, and was still in a column 40 feet high (Graham).

- In 1915, excessive piping caused the Lyman Dam to fail. The earth fill dam was only two years old at the time. The dam was approximately 65 feet high and stored 64.7 million cubic yards (Wahl, 1998).

- In 1982, the Butler dam failed by overtopping. The earth fill dam stored 3.1 million cubic yards, with a lake depth of approximately 25 feet. When breached, the peak outflow reached 1,059 cubic yards per second (Wahl, 1998).

- On October 22, 1997, a mine tailings dam owned by BHP Copper failed due to slope failure. Approximately 300,828 cubic yards of tailings and mine rock tailings were released. The tailings flow now covers approximately 40 acres (Klochko).

7.3.1.3 Probability and Magnitude

The generally accepted safety standard for the design of dams is the Inflow Design Flood (IDF) which is "… the flood flow above which the incremental increase in water surface elevation downstream due to failure of a dam or other water retaining structure is no longer considered to present an unacceptable additional downstream threat" (Interagency Committee on Dam Safety, October 1998). The inflow design flood is the upper limit of the Probable Maximum Flood (PMF), which is the estimated flood flow from the Probable Maximum Precipitation (PMP). The PMP is "… the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year" (US Department of Commerce and US Army Corps of

Engineers, June 1988). However, it must be noted that there are numerous dams in existence whose discharge capabilities were designed and built using methods that are now considered potentially unsafe.

The areas impacted by a dam failure are analyzed on the basis of "sunny day" failures and failures under flood condition. Typically, the dam-break floodplain is more extensive than the floodplain used for land use development purposes and few communities consider upstream dams when permitting development. The potential severity of a full or partial dam failure is influenced by two factors: the amount of water impounded, and the density, type, and value of development and infrastructure downstream.

Currently, comprehensive and directly comparable information on the probability and magnitude of the impact of specific dam failures in Arizona is not available. However, preliminary analysis by the Arizona Department of Emergency Management (ADEM) indicates that dams on the Salt/Verde River, the Aqua Fria River, the Gila River, and the Colorado River pose the greatest threat to the largest population centers within the state. For example, failure of any Bureau of Reclamation dams on the Salt/Verde River or the Aqua Fria River would cause massive flooding in Phoenix and Maricopa County. Failure of Coolidge Dam, a Bureau of Indian Affairs Dam, on the Gila River could cause massive flooding in the Winkelman and Hayden areas of Gila County; Kearny, Florence and the Gila River Indian Reservation in Pinal County; and possibly portions of Maricopa County. Failure of Painted Rock Dam, an Army Corps of Engineers dam, also on the Gila River system, could result in massive flooding of portions of Maricopa and Yuma Counties, including the City of Yuma. Failure of any or all the Bureau of Reclamation dams on the Colorado River could cause flooding, large numbers of injuries, loss of life and massive property damage in Mohave, La Paz and Yuma Counties (Arizona Division of Emergency Management, March 1998).

In addition, the following are two sources of information that provide an indication of the risk posed by specific dams in Arizona and the potential for their failure:

- National Inventory of Dams (NID): FEMA's Hazards US Multi-Hazard (HAZUS-MH) includes data on dams which is based on the National Inventory of Dams (NID) information. The HAZUS-MH / NID database contains information on approximately 77,000 dams in the 50 states and Puerto Rico, with approximately 30 characteristics for each dam, including name, owner, river, nearest city, length, height, average storage, max storage, hazard rating, Emergency Action Plan (EAP), latitude, and longitude. The NID database includes dams that meet the following criteria: it is a high or significant hazard potential class dam or, it is a low hazard potential class dam that exceeds 25 feet in height and 15 acre-feet storage, or it is a low hazard potential class dam that exceeds 50 acre-feet storage and 6 feet height. There are 309 dams in the NID database that are located in Arizona (118 in the NID database only and 191 in both the NID and ADWR database), as shown in Table 7-4.
- Arizona Department of Water Resources (ADWR) Jurisdictional Dams: ADWR has jurisdiction over 254 dams in Arizona (63 in the ADWR database only and 191 in both the NID and ADWR databases) , as shown in Table 7-4. ADWR is responsible for the management of non-federal dams to reduce loss of life and damage to property, and conducts safety inspections of these dams.

Table 7-4: Identified Dams in Arizona, 2002				
County	**NID Only**	**ADWR Only**	**Both NID & ADWR**	**Total**
Apache	16	14	28	58
Cochise	7	3	3	13
Coconino	15	13	25	53
Gila	9	0	5	14
Graham	9	3	25	37
Greenlee	0	1	4	5
La Paz	3	0	0	3
Maricopa	14	7	36	57
Mohave	4	2	4	10
Navajo	2	2	23	27
Pima	11	5	5	21
Pinal	12	1	7	20
Santa Cruz	0	0	4	4
Yavapai	14	12	22	48
Yuma	2	0	0	2
Total	**118**	**63**	**191**	**372**
Note: Dams may be contained within both the NID and ADWR databases.				
Source: NID / HAZUS-MH, ADWR, URS, December 2003				

The NID and ADWR databases provide useful information on the potential hazard posed by dams in Arizona. Each dam in the NID is assigned one of the following three hazard potential classes based on the downstream potential for loss of life and damage to property should the dam fail (listed from best to worst): low, significant, or high. The hazard classes are determined by the anticipated consequences that may occur in the case of the failure or misoperation of the dam or related facilities, as shown in Table 7-5. It is important to note that the hazard potential classification is an assessment of the consequences of failure, but not an evaluation of the probability of failure.

Table 7-5: NID Downstream Hazard Potential Classes		
Hazard Potential Classification	**Loss of Human Life**	**Economic, Environmental, Lifeline Losses**
Low	None expected	Low and generally limited to owner
Significant	None expected	Yes
High	Probable. One or more expected	Yes (but not necessary for this classification)
Note: The hazard potential classification is an assessment of the consequences of failure, but not an evaluation of the probability of failure.		
Source: National Inventory of Dams		

ADWR jurisdiction dams are inspected regularly by ADWR according to NID hazard rating and ADWR safety rating. Assuming that a dam has no safety deficiencies, high hazard dams are inspected annually, significant hazard dams are inspected every three years, and low hazard dams are inspected every five years. Via these inspections, ADWR assigns each dam one of the following four safety ratings (listed from best to worst): no deficiency, safety deficiency, unsafe non-emergency, or unsafe emergency. Note that at the time this analysis was prepared, no ADWR jurisdictional dams had a rating of “unsafe emergency” (the worst safety rating).

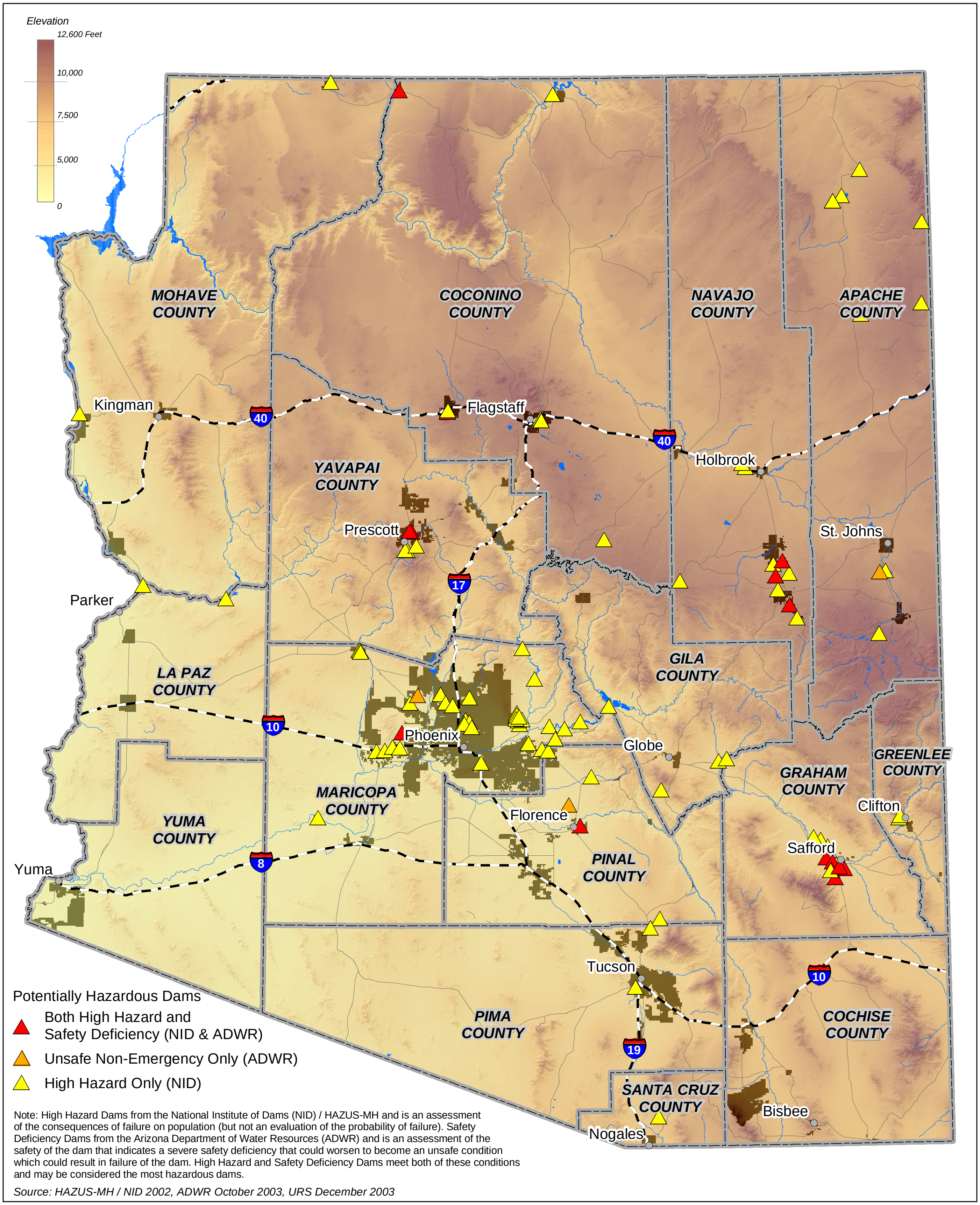
While it is not possible to predict the probability and magnitude of dam failure in Arizona, the NID hazard and ADWR safety ratings can be used to identify potentially hazardous dams in Arizona, as shown in Table 7-6 and Figure 7-1. Of the total 372 dams identified in Arizona, 83 have a "high hazard" rating, with concentrations of these dams in Maricopa, Apache, Navajo, and Graham Counties. Another three dams have a safety rating of "unsafe non-emergency" from ADWR, with these dams located in Apache, Maricopa, and Pinal Counties. Potentially the most hazardous dams in Arizona are the 15 "high hazard" dams that also have "unsafe non-emergency" safety ratings, with concentrations of these dams in Maricopa, Graham, Apache, and Navajo Counties.

Table 7-6: Potentially Hazardous Dams in Arizona, 2002

County	High Hazard Only	Unsafe Non-Emergency Only	Both High Hazard and Unsafe Non-Emergency	Total
Apache	9	1	0	10
Cochise	0	0	0	0
Coconino	6	0	2	8
Gila	2	0	0	2
Graham	6	0	6	12
Greenlee	2	0	0	2
La Paz	2	0	0	2
Maricopa	38	1	1	40
Mohave	2	0	0	2
Navajo	7	0	3	10
Pima	2	0	0	2
Pinal	3	1	1	5
Santa Cruz	1	0	0	1
Yavapai	3	0	2	5
Yuma	0	0	0	0
Total	**83**	**3**	**15**	**101**

Note: High Hazard Only dams from the National Inventory of Dams (NID) / HAZUS-MH and is an assessment of the consequences of failure on population (but not an evaluation of the probability of failure). Unsafe Non-Emergency Only dams from the Arizona Department of Water Resources (ADWR) and is an assessment of the safety of the dam that indicates a severe safety deficiency that could worsen to be come an unsafe condition which could result in failure of the dam. Both High Hazard and Unsafe Non-Emergency Dams meet both of these conditions and may be considered the most hazardous dams.

Source: NID / HAZUS-MH, ADWR, URS, December 2003.



LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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December 2003

State of Arizona
Enhanced Hazard Mitigation Plan

Figure 7-1
Potentially Hazardous Dams in Arizona, 2002

URS

DRAFT

ARIZONA EMERGENCY MANAGEMENT

7.3.1.4 Warning Time

The factors that can cause dam failure are translated into high risks when people or properties are threatened. The National Weather Service (NWS) is responsible for most flood warning efforts in the Arizona, including dam failure flood warnings. For large river systems, hydrological models are used by River Forecast Centers (RFCS). For many—but not all—smaller streams, the NWS has developed an automated system called ALERT (Automated Local Evaluation in Real Time) that does not rely on volunteer observers. However, some communities may still need to use volunteer observers to monitor water levels, the effectiveness of the levee system, or even to back up automated systems.

The NWS has the responsibility for issuing forecasts and warnings to mitigate the loss of life and property associated with weather phenomena for the citizens of the United States. The NWS fulfills this mission with 121 Weather Forecast Offices (WFOs) nationwide that are responsible for collecting data, analyzing mathematical computer models of the atmosphere, and preparing and disseminating weather watches and warnings and disseminating river forecast and warnings. There are 13 River Forecast Centers (RFC) located throughout the United States that provide WFO locations with hydrologic forecasts to be used in the preparation of hydrologic watches and warnings. The NWS is also responsible for the preparation and issuance of public warnings and watches related to eminent or occurring dam failures. The WFOs are responsible for issuance within their appropriate county warning areas. All dams in danger of failing should be reported to the appropriate WFO as soon as possible. The WFOs in coordination with the RFCs will issue products informing the public of the dangers of a dam failure.

Arizona has three NWS forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories). These offices provide warnings with respect to extreme flash floods and to prolonged periods of flooding, both of which could potentially lead to dam failure. In general, the warning time for dam failure can vary from none to days, depending upon the nature of the dam failure. No warning time may be available due to the failure of a dam following a catastrophic earthquake, landslide, or terrorist attack. In the case of extreme flash flooding, the warning time may also be short, although could extend to hours. Periods of prolonged rainfall and associated flooding (e.g., from a tropical storm), the most common cause of dam failure, may have warning times as short as several hours, but more typically would extend to days.

7.3.2 Disease

7.3.2.1 Nature

A disease is a pathological (unhealthy or ill) condition of a living organism or part of the organism that is characterized by an identifiable group of symptoms or signs. Disease can affect any living organism, including people, animals, and plants. Disease can both directly (via infection) and indirectly (via secondary impacts) affect people, animals, and plants. Some diseases can directly affect both people and animals by infecting both. The major concern here is an epidemic, a disease that affects numerous people, animals, or plants at one time.

Of great concern for human, animal and plant health are infectious diseases that are caused by the entry and growth of microorganisms in another living organism. Most, but not all, infectious diseases are contagious, that is communicable by coming into direct or even indirect contact with an organism infected with the disease, something it has touched, or another medium (e.g., water, air).

According to the Centers for Disease Control and Prevention (CDC), during the first half of the twentieth century, optimism grew as steady progress was made against infectious diseases in humans via improved water quality and sanitation, antibiotics, and inoculations (October 1998). The incidences and severity of infectious diseases such as tuberculosis, typhoid fever, smallpox, polio, whooping cough, and diphtheria were all significantly reduced during this period. This optimism proved premature, however, for a variety of reasons, including the following: antibiotics began to lose their effectiveness against infectious disease (e.g., Staphyloccus aureus); new strains of influenza emerged in China and spread rapidly around the globe; sexually transmitted diseases surged; new diseases were identified in the U.S. and elsewhere (e.g., Legionnaires's disease, Lyme disease, toxic shock syndrome, and Ebola hemorrhagic fever); acquired immunodeficiency syndrome (AIDS) appeared; and tuberculosis (including multidrug-resistant strains) reemerged (CDC, October 1998).

In a 1992 report titled *Emerging Infections: Microbial Threats to Health in the United States*, the Institute of Medicine (IOM) identified the growing links between U.S. and international health, and concluded that emerging infections are a major and growing threat to U.S. health. An emerging infectious disease is one whose incidence in humans has increased during the previous decades or threatens to increase in the near future. Emerging infectious diseases are a product of modern demographic and environmental conditions, such as global travel, globalization and centralized processing of the food supply, population growth and increased urbanization.

In response to the threat of emerging infectious diseases, the CDC launched a national effort to protect the US public in a plan titled *Addressing Emerging Infectious Disease Threats*. Based on the CDC's plan, major improvements to the US health system have been implemented, including improvements in surveillance, applied research, public health infrastructure, and prevention of emerging infectious diseases (CDC, October 1998).

Despite these improvements, infectious diseases are the leading cause of death in humans worldwide and the third leading cause of death in humans in the U.S. (American Society for Microbiology, June 21, 1999). A recent follow-up report from the Institute of Medicine, titled *Microbial Threats to Health: Emergence, Detection, and Response*, notes that the impact of infectious diseases on the U.S. has only grown in the last ten years and that public health and medical communities remain inadequately prepared. Further improvements are necessary to prevent, detect, and control emerging, as well as resurging, microbial threats to health. The danger posed by infectious diseases are compounded by other important trends: the continuing increase in antimicrobial resistance; the US' diminished capacity to recognize and respond to microbial threats; and the intentional use of biological agents to do harm (Institute of Medicine, 2003).

The CDC has established a list of over 50 nationally notifiable diseases. A notifiable disease is one that, when diagnosed, health providers are required, usually by law, to report to State or local public health officials. Notifiable diseases are those of public interest by reason of their contagiousness, severity, or frequency. The long list includes such diseases as the following: AIDS; anthrax; botulism; cholera; diphtheria; encephalitis; gonorrhea; Hantavirus pulmonary syndrome; hepatitis (A, B, C); HIV (pediatric); Legionellosis; Lyme disease; malaria; measles; mumps; plague; polio (paralytic); rabies (animal and human); Rocky Mountain spotted fever; rubella (also congenital); Salmonellosis; SARS; Streptococcal disease (Group A); Streptococcal toxic-shock syndrome; *Streptococcus pneumoniae* (drug resistant); syphilis (also congenital); tetanus; Toxic-shock syndrome; Trichinosis, tuberculosis, Typhoid fever; and Yellow fever (Centers for Disease Control and Prevention, May 2, 2003).

In addition to diseases only in humans, there is also significant concern about diseases that affect both humans and animals, known as zoonotic diseases. There are approximately 40 zoonotic diseases, including the following: rabies; tuberculosis and brucellosis; trichinosis; ringworm; giardiasis; and Lyme disease (Will, April 2002).

In Arizona, the Division of Public Health in the Department of Health Services seeks to prevent infectious diseases from entering the state and control those that are endemic or have already entered. Of particular concern to the Division of Public Health are new pandemic diseases, such as SARS, new strains of HIV, new influenza strains, botulism, and bio-terrorism incidents such as anthrax, small pox, or chemical attacks of sarin or VX gas. The Division of Public Health, Office of Infectious Disease Services monitors and controls more than 70 infectious diseases of public health concern such as measles, rubella, pertussis and hepatitis B, diarrhea diseases and vomiting; excluding HIV/AIDS, which is addressed by the Office of HIV/AIDS.

Diseases affecting animals and plants, particularly livestock and agricultural products, are also of major concern. Here, both the supply and quality of human food supplies, potential economic consequences, and impact on foreign trade. According to the National Animal Health Emergency Management System (NAHEMS), an animal health emergency is defined as the appearance of disease with the potential for a sudden negative impact through direct impact on productivity, real or perceived risk to public health, or real or perceived risk to a foreign country which imports from the U.S. (Lautner, April 18, 2002).

A division of the United States Department of Agriculture (USDA), the Animal and Plant Health Inspection Service (APHIS) is responsible for protecting and promoting U.S. agricultural health, administering the Animal Welfare Act, and carrying out wildlife damage management activities. Major programs within APHIS relating to disease are Veterinary Services (VS) and Plant Protection and Quarantine (PPQ). Veterinary Services protects and improves the health, quality, and marketability of animals, animal products and veterinary biologics by (i) preventing, controlling and/or eliminating animal diseases, and (ii) monitoring and promoting animal health and productivity. Among other activities, Veterinary Services conducts surveillance on national animal diseases, foreign animal diseases, emerging animal diseases, and invasive plant species. Most of Veterinary Services efforts are targeted at diseases on the Organization Internationale des Epizooties (OIE) List A or List B.

The OIE is the international standard setting body for animal health and international trade. OIE categorizes animal diseases in two classes: List A -- most serious; and List B -- less serious. List A contains transmissible diseases that have the potential for very serious and rapid spread, irrespective of national borders, that are of serious socio-economic or public health consequence, and that are of major importance in the international trade of animals and animal products. List A includes the following: Foot and mouth disease; foot and mouth disease; lumpy skin disease; bluetongue; African horse sickness; classical swine fever; vesicular stomatitis; rinderpest; contagious bovine pleuropneumonia; Rift Valley fever; sheep pox and goat pox; African swine fever; highly pathogenic avian influenza. The List B disease are transmissible diseases considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of animals and animal products, and number approximately 100 (Organization Internationale des Epizooties, January 9, 2003).

The Plant Protection and Quarantine (PPQ) program, also located within USDA's Animal and Plant Health Inspection Service (APHIS), safeguards agriculture and natural resources from the risks associated with the entry, establishment, or spread of animal and plant pests and noxious weeds. Several thousand foreign plant and animal species have become established in the United States over the past 200 years, with approximately one in seven becoming invasive. An invasive species is an alien (i.e., non-native) species whose introduction does, or is likely to, cause economic or environmental harm or harm to human health. Invasive plants, animals, and pathogens have often reduced the economic productivity and ecological integrity of agriculture, forestry, and the US' other natural resources.

Common vertebrate invasive species in the continental US include nutria, house sparrows, European starlings, and commensal rodents (roof rat, Norway rat, and house mouse). In Hawaii and in some continental U.S. States, feral pigs, goats, and cats have severely impacted natural and environmental resources. Additionally, numerous invertebrate invasive species have become established in the United States, including zebra mussels, imported fire ants, Africanized honey bees, and Asian longhorned beetles (Animal and Plant Health Inspection Service, April 2003).

The Arizona Department of Agriculture (ADA) and Arizona Game and Fish Department (AGFD) are primarily concerned with plant, livestock and wild animal diseases and infections. They focus on diseases listed on the Office International des Epizooties (OIE) disease "A" list. The OIE develops standards and guidelines for use in protecting against incursions of diseases or pathogens during trade in animals and animal products. The agencies are concerned with animal-to-animal diseases, as well as diseases transmitted from animals or arthropod vectors to humans.

Many other hazards, such as floods, earthquakes or droughts, may create conditions that significantly increase the frequency and severity of diseases. These hazards can affect basic services (e.g., water supply and quality, wastewater disposal, electricity), the supply and quality of food, and the public and agricultural health system capacities. As a result, concentrations of diseases may result and grow rapidly, potentially leading to large losses of life and economic value.

In addition, since the anthrax attacks following the terrorist attacks on September 1, 2001, the threat of terrorism using disease to affect humans, animals, or plants, is of growing concern. This is particularly true of those capable of disrupting the human or animal food chain.

7.3.2.2 History

The influenza pandemic of 1918 and 1919, known as the Spanish Flu or Swine Flu, had the highest infectious disease mortality rate in recent history. More than 20 million persons were killed worldwide, some 500,000 of which were in the U.S. alone (Centers for Disease Control and Prevention, October 1998). More recent major infectious diseases affecting people in the U.S. include the following:

- West Nile Virus WNV, a seasonal infection transmitted by mosquitoes, grew from an initial U.S. outbreak of 62 disease cases in 1999 to 4,156 reported cases, including 284 deaths, in 2002 (Centers for Disease Control and Prevention, July 8, 2003).
- Severe accurate respiratory syndrome (SARS), which is estimated to have killed 916 and infected 8,422 worldwide by mid-August 2003 (World Health Organization, August 15, 2003). In the U.S., there were 175 suspect cases and 36 probable cases, although no reported deaths (Centers for Disease Control and Prevention, July 17, 2003).
- Although most cases go unrecognized, Norwalk-like virus (NLV) is believed to affect over 20 million persons in the U.S. each year. NLV accounts for 96 percent of all non-bacterial outbreaks of gastroenteritis (Arizona Department of Health Services, March/April 2003).

Significant animal disease outbreaks that affected major U.S. trading partners, resulting in huge economic losses, include the following:

- The largest recent animal disease outbreak in the United States occurred in 1983-84, when avian influenza swept through Pennsylvania and neighboring States. Poultry prices for consumers jumped by $350 million. A 6-month eradication plan cost the Federal Government $63 million (Federal Emergency Management Agency, July 2002).
- In 1988, the value of British beef and beef products was estimated at US $880 million. After bovine spongiform encephalopathy (BSE, or "mad cow disease") emerged, its value dropped considerably. After a 1996 announcement of a probable link between consumption of BSE-affected meat and a new variant of Creutzfeld-Jakob disease in humans, the value fell to zero (Federal Emergency Management Agency, July 2002).
- The pig husbandry industry in the Netherlands was struck by a severe epidemic of Classical Swine Fever (CSF) in 1997, resulting in the killing of up to 1.1 million pigs (Bouma and Stegeman). Other countries affected by CSF include Haiti, the Dominican Republic, and the U.K. (Lautner, March 18, 2002).
- Approximately 1.1 million pigs were killed in Malaysia in the two years 1998 and 1999 in order to stop a major outbreak of the Nipah Virus. The virus also affects people and resulted in the death of at least 115 persons (Animal Production and Health Commission for Asia and the Pacific, January 2002).
- More than a million cattle and sheep were destroyed in the U.K. due to an outbreak of foot-and-mouth disease in 2001. Other countries affected by foot-and-mouth disease include Argentina, Brazil, Egypt Taiwan Korea, Japan, and South Africa (Lautner, March 18, 2002).

According to figures provided by Cornell University, invasive species cost the United States more than $138 billion each year (Animal and Plant Health Inspection Service, April 2003). The following are examples of the impacts of a number of invasive species in the U.S.:

- Boll weevils came to the United States from Mexico in 1892 and are the primary insect pest of cotton, costing U.S. farmers more than $200 million annually in control efforts and yield losses (Animal and Plant Health Inspection Service, April 2003).
- In 1970, leaf blight destroyed about $1 billion worth of corn in the United States. Between 1993 and 1998, fusarium head blight affected successive wheat harvests in the Dakotas, Minnesota, and Manitoba. The

disease spread over 10 million acres, probably with the help of abnormally wet weather, and cost an estimated $1 billion in lost production (Federal Emergency Management Agency, July 2002).

- An invasive insect detected in California in the early 1990s, the glassy–winged sharpshooter carries the plant bacterium Xylella fastidiosa, which causes a variety of plant diseases, including Pierce's disease. This disease has already caused multi–million–dollar losses of California grape crops and continues to pose a major threat to the grape, raisin, and wine industries, and the tourism associated with them (Animal and Plant Health Inspection Service, April 2003).
- Tropical bont tick is present on the Caribbean Islands and is a pest of concern to the U.S. mainland due to frequent travel and commerce between the areas. It can carry a parasite that causes heartwater disease—a major threat to domestic livestock (Animal and Plant Health Inspection Service, April 2003).

In Arizona, there have been 13 disaster declarations (Presidential, USDA, or Gubernatorial disaster or emergency declaration) due to disease and 19 additional undeclared events, as shown in Table 7-3. These resulted in an identified 60 fatalities and 82 injuries. Major infectious disease outbreaks in Arizona that affected humans include the following:

- In 1883, a smallpox epidemic struck the then small village of Mesa, and killed 15 percent of the town's population, 44 persons out of 300 (Mesa Tribune).
- In 1918 the Spanish influenza pandemic entered Arizona resulting in a great number of deaths, although the exact number is undocumented.
- In 1952, large numbers of influenza cases were reported in the state, although no death statistics are available.
- In 1993, the Hanta virus killed 11 people on the Navajo Nation (CNN, October 15, 1995).
- In 2002, Arizona experienced two major outbreaks of the Norwalk-like virus (NLV). More than 70 persons were affected at a Maricopa County golf tournament resulting in the death of a teenage boy. Infected drinking water and ice was implicated at the golf tournament. Also, contaminated river water affected 40 rafters at the Grand Canyon (Arizona Department of Health Services, March/April 2003).

There have been relatively few reported incidents or concerns related to animal disease outbreaks in Arizona, including the following:

- On May 18, 2002 the Arizona Game and Fish Department placed an emergency ban on the importation of live hoofed animals (e.g., deer and elk) into Arizona due to a fear of Chronic Wasting Disease (CWD). CWD is a disease closely related to "mad cow disease" in cattle and scrapie in domestic sheep and goats but affects dear and elk (Arizona Game and Fish).
- In May 1998, a horse near Kingman, Arizona was diagnosed with Vesicular Stomatitis (VS), a contagious disease of horses and livestock. The disease looks similar to hoof and mouth disease, but does not have a high mortality rate. A widespread outbreak of VS would adversely impact the states cattle and equine industries (Arizona Department of Agriculture, May 21, 1998).
- On January 8, 2003, the Arizona Department of Agriculture issued an Administrative Order implementing procedures to prevent the introduction of Exotic Newcastle Disease (END) into Arizona. END is a contagious and fatal viral disease affecting domestic, wild, and caged poultry and birds, and is one of the most infectious diseases of poultry in the world. On February 5, 2003, Governor Napolitano declared a state of emergency to contain END threatening Arizona's poultry. The US Secretary of Agriculture, Ann M. Veneman, signed declarations of extraordinary emergency with respect to END in Arizona on February 7, 2003 (Arizona Department of Agriculture, January 8, 2003; United States Department of Agriculture, February 12, 2003).

Arizona has been subject to a number of major infestations, the largest of which is still affecting the state (pine bark beetle). Further details on these infestations are given below:

- On May 22, 2003, Governor Janet Napolitano declared a State disaster and a state of emergency due to the ravages of the pine bark beetle on the state's forests. An estimated 2.5 million ponderosa pines and 4 million pinon pines were killed by the pine bark beetle in Arizona in 200. The last significant bark beetle outbreak in Arizona occurred from 1951 to 1956. The bark beetles are killing so many trees for two reasons, first the forest has too many trees and second the trees are very dry. Overcrowded forest conditions coupled with drought lead to the high probability of beetle attack. The forests of Arizona have been able to survive in relatively dry conditions because in past centuries low intensity fires helped to maintain a low density of trees in the forest. Whereas, in the past century we have controlled fire which allowed many forested areas to become overcrowded (DeGomez, April 23, 2003).
- Exotic and imported ants are listed on the Arizona Department of Agriculture website as "Arizona's Most Unwanted Pest". Some people are allergic to the sting and in some cases may cause death. Fire ants are also known to out compete and drive away local native ants (Arizona Department of Agriculture).
- Arizona periodically experiences major grasshopper infestations. Four infestations have resulted in State declarations of emergency in the last quarter century (Arizona Division of Emergency Management, March 6, 2003).
- A declared plant disease disaster involved the wheat disease, Karnal Bunt in 1996. Other undeclared plant disease events include the citrus disease red scale in 1942 (Arizona Division of Emergency Management, March 6, 2003).

7.3.2.3 Probability and Magnitude

The probability and magnitude of disease, particularly an epidemic, is difficult to evaluate due to the wide variation in disease characteristics, such as rate of spread, morbidity and mortality, detection and response time, and the availability of vaccines and other forms of prevention. A review of the historical record (see above) indicates that disease related disasters do occur in humans, animals, and plants with some regularity and severity. There is growing concern, however, about emerging infectious diseases as well as the possibility of a bioterrorism attack.

7.3.2.4 Warning Time

Due to the wide variation in disease characteristics, the warning time for a disease disaster can vary from no time to months, depending upon the nature of the disease. No warning time may be available due to an extremely contagious disease, particularly if combined with a terrorist attack in a crowded environment. Balancing this are the numerous agencies and programs in place to prevent, detect, and respond to diseases, such as the Centers for Disease Control and Prevention, Arizona Department of Health Services, Organization Internationale des Epizooties, USDA Animal and Plant Health Inspection Service, USDA Plant Protection and Quarantine, and Arizona Department of Agriculture.

7.3.3 Drought

7.3.3.1 Nature

Drought is a normal part of virtually every climate on the planet, including in areas of high and low rainfall. It is different from normal aridity, which is a permanent characteristic of the climate in areas of low rainfall. Drought is the result of a natural decline in the expected precipitation over an extended period of time, typically one or more seasons in length. The severity of drought can be aggravated by other climatic factors, such as prolonged high winds and low relative humidity (FEMA, 1997).

Drought is a complex natural hazards which is reflected in the following four definitions commonly used to describe it:

- Meteorological drought is defined solely on the degree of dryness, expressed as a departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
- Hydrological drought is related to the effects of precipitation shortfalls on streamflows and reservoir, lake, and groundwater levels.
- Agricultural drought is defined principally in terms of soil moisture deficiencies relative to water demands of plant life, usually crops.
- Socioeconomic drought associates the supply and demand of economic goods or services with elements of meteorological, hydrologic, and agricultural drought. Socioeconomic drought occurs when the demand for water exceeds the supply as a result of weather-related supply shortfall. The may also be called a water management drought.

A drought's severity depends on numerous factors, including duration, intensity, and geographic extent as well as regional water supply demands by humans and vegetation. Due to its multi-dimensional nature, drought is difficult to define in exact terms and also poses difficulties in terms of comprehensive risk assessments.

Drought differs from other natural hazards in three ways. First, the onset and end of a drought are difficult to determine due to the slow accumulation and lingering of effects of an event after its apparent end. Second, the lack of an exact and universally accepted definition adds to the confusion of its existence and severity. Third, in contrast with other natural hazards, the impact of drought is less obvious and may be spread over a larger geographic area. These characteristics have hindered the preparation of drought contingency or mitigation plans by many governments.

Droughts may cause a shortage of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality may also decline and the number and severity of wildfires may increase. Severe droughts may result in the loss of agricultural crops and forest products, undernourished wildlife and livestock, lower land values, and higher unemployment.

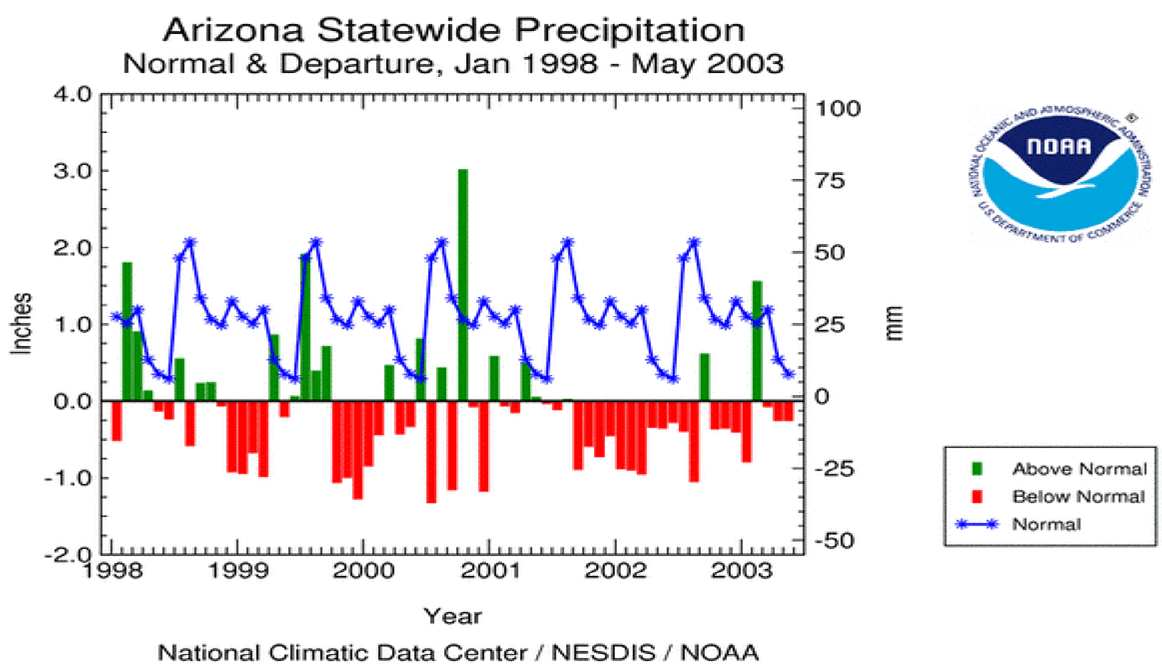
7.3.3.2 History

During the 20th century, nine notable droughts have occurred in the United States. While damage estimates are not available for most, estimates suggest that the 1976-1977 drought in the Great Plains, Upper Midwest, and far Western States caused direct losses of $10-15 billion. Furthermore, the drought in the Central and Eastern States during 1987-89 caused an estimated $39 billion in damages (FEMA, 1997).

Arizona has experienced 17 droughts declared drought disasters/emergencies and 93 drought events (droughts affect multiple years are recorded as a distinct event for each year affected), as shown in Table 7-3. Between 1849 and 1905, the most prolonged period of drought conditions in 300 years occurred in Arizona (NOAA, July 29, 2003). Another period of prolonged drought occurred during the period 1941 to 1965, during which time there were no spill releases into the Salt River (Arizona Division of Emergency Management, December 2001). Data collected by the National Climatic Data Center, as shown in

Figure 7-2 shows that between 1998 and 2003 there have been more months with a below normal amount of precipitation than those months with above normal precipitation. Especially from mid 2001 to mid 2002, there has been a continuous below normal amount of precipitation.

Figure 7-2: Arizona Statewide Precipitation, Normal and Departure, Jan 1998-May 2003



Source: NOAA, May 2003.

At the time of this writing, Arizona is experiencing drought and conditions are particularly acute in the northern plateau. According to the City of Phoenix Water Services, the City and much of Arizona, is in its fourth consecutive year of below average rainfall, and is below average for six out of the last seven years. Surface water flows and reservoir storage levels are the lowest ever recorded in many areas. Rural areas are most affected due to heavy reliance on dwindling ground water supplies and lack of alternatives. The cities of Phoenix and Tucson are less affected thanks to supplies from the Central Arizona Project (CAP), the Salt River Project (SRP), significant investments in recharge systems, and ground water sources (Jacobs and Morehouse, June 11-13, 2003).

According to the local newspapers, most rural communities draw from a limited number of lakes and wells in a confined watershed. The Tohono O'odham Nation declared a drought emergency in May 2002. The cities of Williams and Flagstaff are experiencing severe water shortages with Flagstaff instituting mandatory water restrictions on residents. The Navajo Nation is particularly hard hit by the drought. Many wells and basins are dry leaving little water for livestock. The land is in poor condition after years of overgrazing and so Navajo leaders are encouraging the sale of animals or their removal from the reservation. Other ranchers throughout the state are faced with the choice of buying feed for their cattle or selling the herd. The Cochise County agricultural extension agent estimates that rancher's herds there are now at 50 percent of pre-drought sizes, and cattle prices are low. State officials classify 85 percent of the state's rangeland as poor or very poor. Arizona and New Mexico are assessed to have the poorest range and pasture land in the United States. By January 2003, losses to Arizona's cattle were estimated at up to $300 million (Climate Assessment for the Southwest, May 23, 2003).

Despite the on-going drought, Arizona is one 15 states nationwide that lack a statewide drought plan. However, the State is taking action to address this shortfall. On March 20, 2003, Governor Janet Napolitano signed Executive Order 2003-12 directing the establishment of the Arizona Drought Task Force. The Task Force is lead by the

Department of Water Resources and is comprised of State agencies and elected officials. The task force is charged with creating work groups to address problems in: municipal and industrial water supply, agriculture, wildlife and wildlife habitat, conservation education, and fire suppression. Within the State some counties and municipalities, however, do have existing drought mitigation plans. These include Graham and Navajo Counties, and the Cities of Phoenix and Peoria. (Jacobs and Morehouse, June 11-13, 2003).

It is also important to note that in addition to affecting people, drought may severely affect livestock and pets. Such events may require the emergency watering/feeding, shelter, evacuation, and event burying of animals, such as during statewide droughts during the 1990's affecting range animals and resulting in range closures and the institution of dry-milk programs (Lanman, May 27, 2003).

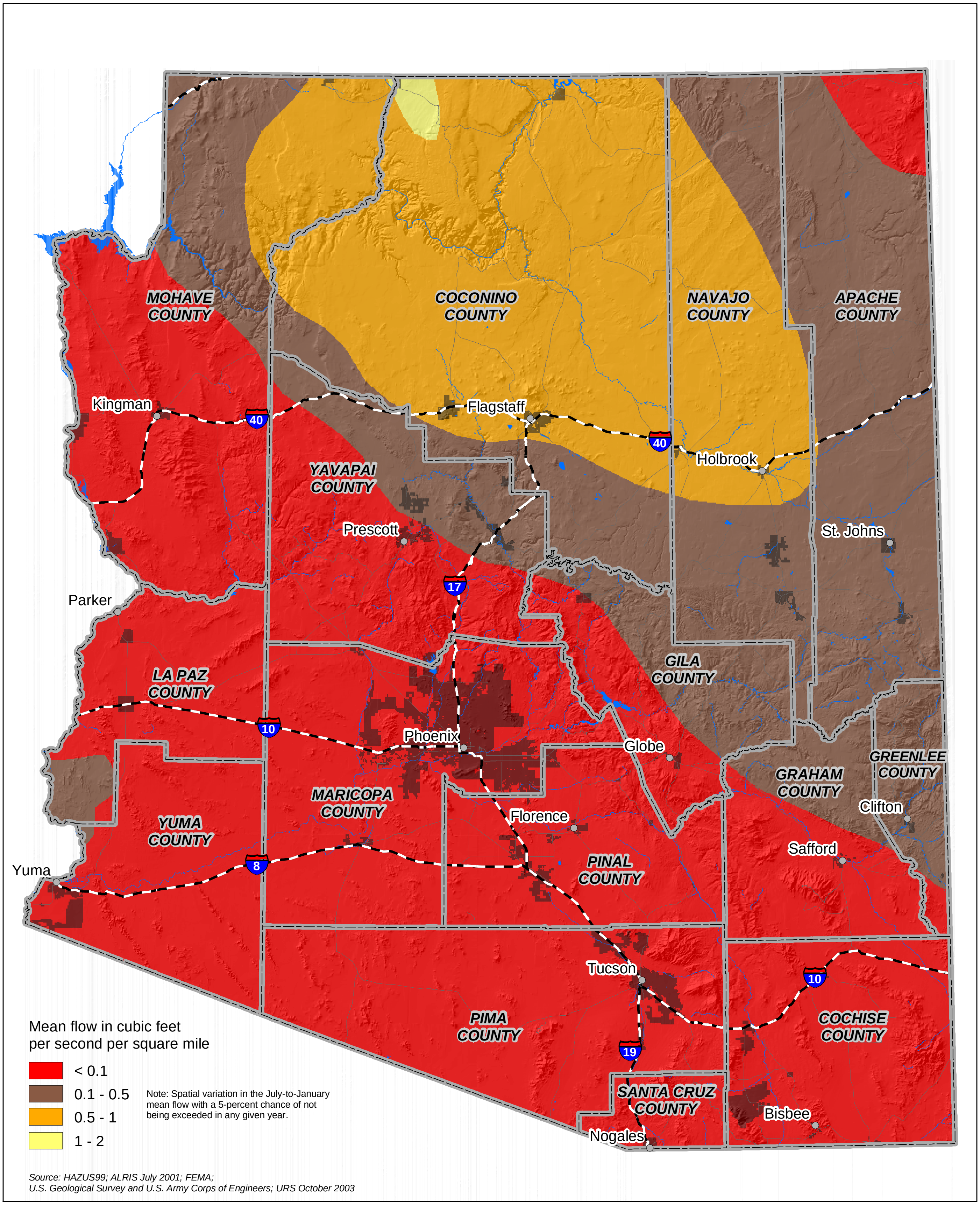
7.3.3.3 Probability and Magnitude

No commonly accepted approach exists to assessing risks associated with drought. The Palmer Drought Severity Index (PSDI) is a commonly used index that measures the severity of drought for agriculture and water resource management. It is calculated from observed temperature and precipitation values and estimates soil moisture. However, the Palmer Index is not considered to be consistent enough to characterize the risk of drought on a nationwide basis (FEMA, 1997).

The principal objective of the *National Study of Water Management During Drought* was to develop strategies for improving water management to reduce the nation's vulnerability to drought (USACE, September 1995). An outcome of this study was the *National Drought Atlas*, which was managed by the United States Army Corps of Engineers and is the first nationwide study of drought frequency. The *Atlas* provides a useful tool for answering questions about the likely duration, timing, and severity of drought in a region (Willeke et al, 1994). It is based on precipitation, stream flow, and Palmer Drought Severity Index data from 1,119 sites (grouped into 111 regions) in the National Climate Data Center's Historical Climate Network (with an average record length of 85 years).

While there is no commonly accepted return period or non-exceedance probability for defining the risk from hydrological drought (such as the 100-year or 1 percent annual chance of flood), as noted above, the *National Drought Atlas* can be used to answer questions on drought at the regional level (FEMA, 1997). Figure 7-3 shows July-to-January mean stream flow in cubic feet per second per square mile with a 5-percent chance of non-exceedance (meaning that stream flow will be less than this value once in every twenty years). The map indicates that the southern half of Arizona will be subject to a drought every twenty years in which mean streamflows are 0.1 cubic feet per second per square mile or less. According to ADEM's *State of Arizona Hazard Identification Study - Draft* (March 1998), the entire state is susceptible to a drought at any time, though the drought season tends to be from January through May.

It is notable that temperatures in the Western U.S. rose 2-5°F during the 20th century. While this increase was accompanied by precipitation increases of up to 50 percent in some areas of the West, some places have become drier and experienced more droughts (including Arizona). The two major climate change models, the Canadian Model and the Hadley Model, both forecast continued temperature increases in the West of 5-11°F during the 21st century, including Arizona. However, both models also forecast significant increases in rainfall in much of the West, with the increase on the order of 75-100 percent across much of Arizona. These increases may lead to increased water supplies, although current reservoir systems may be inadequate to control earlier spring runoff and to maintain supplies for the summer (National Assessment Synthesis Team, May 2001).



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Interstate
City
County
County Seat
Highway
Major Stream
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0 25 50
Miles

State of Arizona
Enhanced Hazard
Mitigation Plan

Figure 7-3

Hydrologic Drought in Arizona

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When attempting to evaluate the probability and magnitude of drought in Arizona, it is useful to consider the amount and sources of water in Arizona. Arizona used 6.8 million acre-feet of water in 1994, as shown in Table 7-7. This water came from two major sources, surface water and groundwater. Surface water supplied 54.0 percent of Arizona's water and comes from three sources, the Colorado River, the Central Arizona Project (CAP) Canal (which comes from the Colorado River), and in-state rivers (including streams and lakes). This surface water is a major renewable resource for Arizona, but can vary dramatically between years, seasons, and locations due to the state's desert climate. In order to lessen the impact of such variations, water storage reservoirs and delivery systems have been constructed throughout the state, the largest of which are located on the Salt River, Verde River, Gila River, and Agua Fria River.

Table 7-7: Sources of Water Used in Arizona, 1994

Source	Acre Feet	Percent
Surface Water		
Colorado River	1,421,000	20.9
CAP Canal	808,000	11.9
In-State Rivers	1,427,000	21.0
Sub-Total Surface Water	3,656,000	53.8
Ground Water	3,024,000	44.5
Reclaimed Water	120,000	1.8
Total	**6,800,000**	**100**

Source: Arizona Department of Water Resources.

The other major source of water is groundwater, which supplied 44.5 percent of Arizona's water in 1994. This water has been pumped out of natural reservoirs beneath the surface known as aquifers, which have been created over millions of years. While a significant supply of water remains stored in aquifers, groundwater has historically been pumped out much more rapidly than it is replenished, thereby creating a condition known as overdraft and leading to limits to its availability by location, depth, and quality. In 1980, Arizona implemented the Groundwater Management Code in order to promote conservation and long-range planning of water resources, including reducing reliance on groundwater supplies.

Reclaimed water, or effluent, is the only increasing source of water in the state, although it only constituted 1.8 percent of the water used in 1994. As the state's population grows, however, increasing amounts of reclaimed water will be available for purposes such as agriculture, golf courses, parks, industrial cooling, and maintenance of wildlife areas.

Much of Arizona, particularly the major metropolitan areas of Phoenix and Tucson, are in a rather unique position. While located in a region subject to hydrological drought, as evidenced by Figure 7-3, a large supply of water is available via the Central Arizona Project (CAP) Canal. The CAP Canal is a 336-mile long system of aqueducts, tunnels, pumping plants, and pipelines running from the Colorado River on the Arizona-California border eastward to the Phoenix area and then southeast to the Tucson area. The CAP Canal supplies approximately 1.5 million acre-feet of water annually to Maricopa, Pinal, and Pima Counties and is the largest single source of renewable water supply in the state. The CAP Canal has more than 80 major customers, approximately 75 percent of which are municipal and industrial users, 13 percent are irrigation districts, and 12 percent are Indian communities (Arizona Department of Water Resources; Central Arizona Project).

7.3.3.4 Warning Time

The U.S. Drought Outlook forecasts the drought outlook for the U.S. for the remaining part of the month of issue plus the next three months. This report is prepared monthly by the National Weather Service's Climate Prediction Center (CPC). Tools used in preparing the drought outlook include the following: the official CPC long-lead precipitation outlook for the next 90 days; the Palmer Drought Index probability projections for the next 3 months; various medium and short-range forecasts and models, such as the 6-10 day and 8-14 day forecasts and the 2-week soil moisture forecast; and the constructed analogue from soil moisture forecasts (National Weather Service, Climate Prediction Center).

A more short-term drought outlook is the U.S. Drought Monitor, which provides a weekly summary of the extent and intensity of current drought conditions across the U.S. It is a joint effort product from the Climate Prediction Center (CPC) and National Climatic Data Center (NCDC), the U.S. Department of Agriculture, and the National Drought Mitigation Center (NDMC). Tools used to prepare the U.S. Drought Monitor include the following: climate outlooks; seasonal U.S. drought outlook; stream flow forecast; forecast Palmer Drought Index; and soil moisture forecasts (National Drought Mitigation Center).

Droughts typically take months or even years to occur and be identified, and may also persist for years. As noted above, the U.S. Drought Outlook provides some warning time, perhaps months about the occurrence of a drought. The U.S. Drought Monitor provides information on the extent and severity of existing drought conditions. The information from both of these may provide warning time on the order of months which be used to plan for future or existing drought conditions.

7.3.4 Earthquake

7.3.4.1 Nature

An earthquake is "…a sudden motion or trembling caused by an abrupt release of accumulated strain the tectonic plates that comprise the earth's crust." These rigid plates, known as tectonic plates, are some 50 to 60 miles in thickness and move slowly and continuously over the earth's interior. The plates meet along their edges, where they move away, past or under each other at rates varying from less than a fraction of an inch up to five inches per year. While this sounds small, at a rate of two inches per year, a distance of 30 miles would be covered in approximately one million years (FEMA, 1997).

The tectonic plates continually bump, slide, catch, and hold as they move past each other which causes stress accumulates along faults. When this stress exceeds the elastic limit of the rock, an earthquake occurs, immediately causing sudden ground motion and seismic activity. Secondary hazards may also occur, such as surface faulting, ground failure, and tsunamis. While the majority of earthquakes occur near the edges of the tectonic plates, earthquakes may also occur at the interior of plates.

The vibration or shaking of the ground during an earthquake is described by ground motion. The severity of ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. Ground motion causes waves in the earth's interior, also known as seismic waves, and along the earth's surface, known as surface waves. The following are the two kinds of seismic waves:

- P (primary) waves are longitudinal or compressional waves similar in character to sound waves that cause back-and-forth oscillation along the direction of travel (vertical motion), with particle motion in the same direction as wave travel. They move through the earth at approximately 15,000 mph.
- S (secondary) waves, also known as shear waves, are slower than P waves and cause structures to vibrate from side-to-side (horizontal motion) due to particle motion at right-angles to the direction of wave travel. Unreinforced buildings are more easily damaged by S waves.

There are also two kinds of surface waves, Raleigh waves and Love waves. These waves travel more slowly and typically are significantly less damaging than seismic waves.

Seismic activity is commonly described in terms of magnitude and intensity. Magnitude (M) describes the total energy released and intensity (I) subjectively describes the effects at a particular location. Although an earthquake has only one magnitude, its intensity varies by location. Magnitude is the measure of the amplitude of the seismic wave and is expressed by the Richter scale. The Richter scale is a logarithmic measurement, where an increase in the scale by one whole number represents a tenfold increase in measured amplitude of the earthquake. Intensity is a measure of how strong the shock felt at a particular location, expressed by the Modified Mercalli Intensity (MMI) scale.

Another way of expressing an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity. If an object is dropped while standing on the surface of the earth (ignoring wind resistance), it will fall towards earth and accelerate faster and faster until reaching terminal velocity. The acceleration due to gravity is often called "g" and is equal to 9.8 meters per second squared (980 cm/sec/sec). This means that every second something falls towards earth, it velocity increases by 9.8 meters per second. Peak ground acceleration (PGA) measures the rate of change of motion relative to the rate of acceleration due to gravity. For example, acceleration of the ground surface of 244 cm/sec/sec equals a PGA of 25.0 percent.

Table 7-8: Earthquake PGA, Magnitude and Intensity Comparison

PGA (%g)	Magnitude (Richter)	Intensity (MMI)	Description (MMI)
<0.17	1.0 - 3.0	I	I. Not felt except by a very few under especially favorable conditions.
0.17 - 1.4	3.0 - 3.9	II - III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
1.4 - 9.2	4.0 - 4.9	IV - V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
9.2 - 34	5.0 - 5.9	VI - VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
34 - 124	6.0 - 6.9	VII - IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
>124	7.0 and higher	VIII or higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: Wald, Quitoriano, Heaton, and Kanamori, 1999.

It is possible to approximate the relationship between PGA, the Richter scale, and the MMI, as shown in Table 7-8. The relationships are, at best, approximate, and also depend upon such specifics as the distance from the epicenter and depth of the epicenter. An earthquake with 10.0 percent PGA would roughly correspond to an MMI intensity of V or VI, described as being felt by everyone, overturning unstable objects, or moving heavy furniture.

One of the secondary hazards from earthquakes is surface faulting, the differential movement of two sides of a fault at the earth's surface. Linear structures built across active surface faults, such as railways, highways, pipelines, and tunnels, are at high risk to damage from earthquakes. Displacement along faults, both in terms of length and width, varies but can be significant (e.g., up to 20 feet), as can the length of the surface rupture (e.g., up to 200 miles).

Earthquake-related ground failure, due to liquefaction, is another secondary hazard. Liquefaction occurs when seismic waves pass through saturated granular soil, distorting its granular structure, and causing some of the empty spaces between granules to collapse. Pore-water pressure may also increase sufficiently to cause the soil to behave like a fluid (rather than a soil) for a brief period and causing deformations. Liquefaction causes lateral spreads (horizontal movement commonly 10-15 feet, but up to 100 feet), flow failures (massive flows of soil, typically hundreds of feet, but up to 12 miles), and loss of bearing strength (soil deformations causing structures to settle or tip).

7.3.4.2 History

A total of 42 major earthquakes affecting Arizona were identified, as shown in Table 7-3. Only one of these events resulted in a disaster/emergency declaration. A total of eight fatalities were recorded, no injuries, and no damages. The Arizona Geological Survey (AZGS) has prepared a map displaying the intensity of historical earthquakes that have affected Arizona using the Modified Mercalli Intensity (MMI) scale, as shown in Figure 7-4. The southeastern and southwestern corners of the state have historically been subject to the greatest intensity earthquakes. The earthquakes affecting the southeastern corner originated in Mexico. Those in the southwestern corner, affecting primarily Yuma, originated in southern California and northern Mexico. A zone of lesser ground shaking intensity extends from around Flagstaff northward.

The earliest descriptions of earthquakes in Arizona are those recorded at Fort Yuma, located in the 1800's on the California side of the Colorado River. Shocks that probably centered in the Imperial Valley of California, or in Mexico, have been noted there since late 1852. While no earthquake in recorded history has caused deaths or injuries in Arizona, there have been 14 tremors of intensity V to VII have centered within Arizona's borders (United States Geological Survey, September 12, 2003).

Most major seismic events have occurred in the past outside the state near the southeastern and southwestern corners. Within Arizona, earthquakes have most commonly occurred between Flagstaff and the Grand Canyon. The following are examples of major earthquakes that have affected and/or occurred within Arizona:

- The earliest recorded earthquake affecting Arizona, and possibly the largest, occurred in 1830. With an estimated Modified Mercalli Intensity (MMI) of IX recorded at San Pedro, approximately 25 miles west of Tucson, the earthquake would have caused massive damage to built structures (ADEM, March 1998).

- The 1887 Sonoran earthquake caused significant destruction in Southern Arizona towns, including Tucson, and was one of the largest earthquakes in North American history. The epicenter was located a hundred or so miles south of Douglas, Arizona, along the Pitaycachi fault in Mexico, and caused great destruction at its epicenter. The quake was so large that it was felt from Guaymas, Mexico to Albuquerque, New Mexico, and was probably felt in Phoenix. It is estimated variously to have been an intensity MMI VII and magnitude (M) 7.2 earthquake. In Arizona, water in tanks spilled over, buildings cracked, chimneys were toppled, and railroad cars were set in motion. An observer at Tombstone, near the Mexican border, reported sounds ``like prolonged artillery fire.'' (ADEM, March 1998; Bausch and Brumbaugh, May 23, 1994; USGS, September 12, 2003; University of Arizona).

With the increase in development, if such a quake occurred today it would cause extensive damage in southeastern Arizona (Jenny and Reynolds, 1989).

- Northern Arizona experienced a rash of earthquakes in the early part of this century. The first recorded quake in Arizona history was a M 6.2 that rattled Flagstaff in 1906. The same area saw almost non-stop seismic activity for 13 days in September of 1910, with the quakes gaining in intensity throughout this period and culminating in a M 6.0 earthquake that prompted residents to leave the area. In 1912, another M 6.2 earthquake shook the Flagstaff region, this one large enough to cause damage to homes in Williams and create a 50-mile long fissure north of the San Francisco Mountains (ADEM, March 1998; University of Arizona).

- The first damaging earthquake known to have centered within Arizona's borders occurred on January 25, 1907, and caused violent shaking in Flagstaff. This was the year of the great San Francisco earthquake and of a damaging series of shocks at Socorro, New Mexico (USGS, September 12, 2003).

- From September 10 to 23, 1910, a series of 52 earthquakes caused a construction crew in the Coconino Forest near Flagstaff to break camp and leave the area as boulders rolled down on the camp from nearby mountains. The shocks grew in intensity over the two-week period until September 23, when a very strong shock raged throughout northern Arizona. The quake was so severe north of the San Francisco Mountains that Indians fled from the region (USGS, September 12, 2003).

- On August 8, 1912, an earthquake caused a 50-mile-long crack in the earth north of the San Francisco Range, damaging houses at Williams. The shock was strong in Coconino County, north of Flagstaff, where rockslides roared down the mountainsides, and the earth seemed to roll ``like waves on the Colorado River.'' (USGS, September 12, 2003).

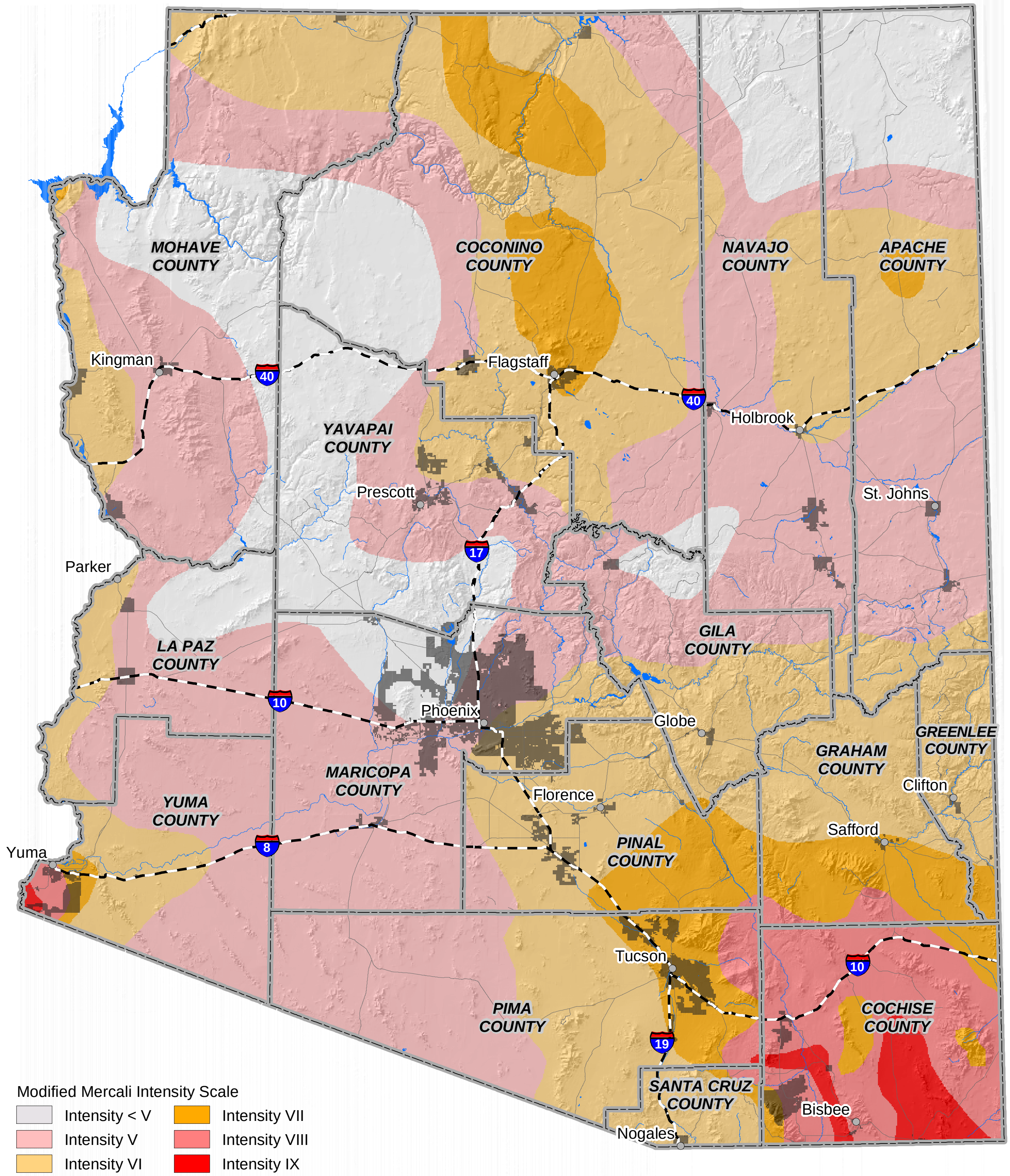
- An earthquake cracked walls and plaster at Wellton on January 2, 1935, located a few miles east of Yuma in southwestern Arizona. While few residents of the small town were frightened by the tremor, everyone felt the ground quiver, and homes shake (USGS, September 12, 2003).

- On January 10, 1935, a slightly stronger earthquake awakened sleepers at Grand Canyon, 175 miles north of Phoenix. The distinct subterranean rumble and the movement of houses frightened many. Walls were cracked in some cases, and rockslides occurred in the mountains. Grand Canyon residents felt three slight foreshocks during the first week of January, and one very minor aftershock was noted on January 15 (USGS, September 12, 2003).

- A strong earthquake rocked Apache County on January 16, 1950, leaving several cracks in the ground as it rumbled through the small town of Ganado. The cracks, one-half inch wide and up to 12 feet long, extended in a north-south direction near the Ganado trading post (USGS, September 12, 2003).

- Yuma has experienced repeated damage from California earthquakes, such as the M 7.1 on May 18, 1940, the M 6.5 on October 15, 1979, and the M 6.4 on December 19, 1979 (ADEM, March 1998; Bausch and Brumbaugh, May 23, 1994).

A total of ten major earthquakes were recorded during the 1800’s and another 32 recorded during the 1900’s. Numerous smaller earthquakes, however, have been recorded throughout the 1900’s (see Bausch and Brumbaugh, May 23, 1994).



Source: HAZUS99; ALRIS July 2001; Peachtree and Bausch, 1999; URS October 2003

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LEGEND

Interstate
City
County
County Seat
Highway
Major Stream
Lake

N

0 25 50
Miles

State of Arizona
Enhanced Hazard
Mitigation Plan

URS

Figure 7-4

Maximum Intensity Ground Shaking and Earthquake Damage in Arizona, 1887-1999

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December 2003

7.3.4.3 Probability and Magnitude

Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as peak ground acceleration (PGA), over a specified period of years. For example, Figure 7-5, displays the probability of exceeding a certain ground motion, expressed as PGA, in 50 years in the Western United States. This is a common earthquake measurement that shows three things: the geographic area affected, all colored areas on the map; the probability of an earthquake of each level of severity, 10.0 percent chance in 50 years; and the severity, the peak ground acceleration (PGA) as indicated by color.

Note that this map expresses a 10.0 percent probability of exceedance and, therefore, there is a 90.0 percent chance that the peak ground acceleration displayed will not be exceeded during 50 years. The use of a 50-year period to characterize the percent chance of exceedance is arbitrary and does not imply the structures are thought to have a useful live of only 50 years. Similar maps exist for other measures of acceleration, probabilities, and time periods.

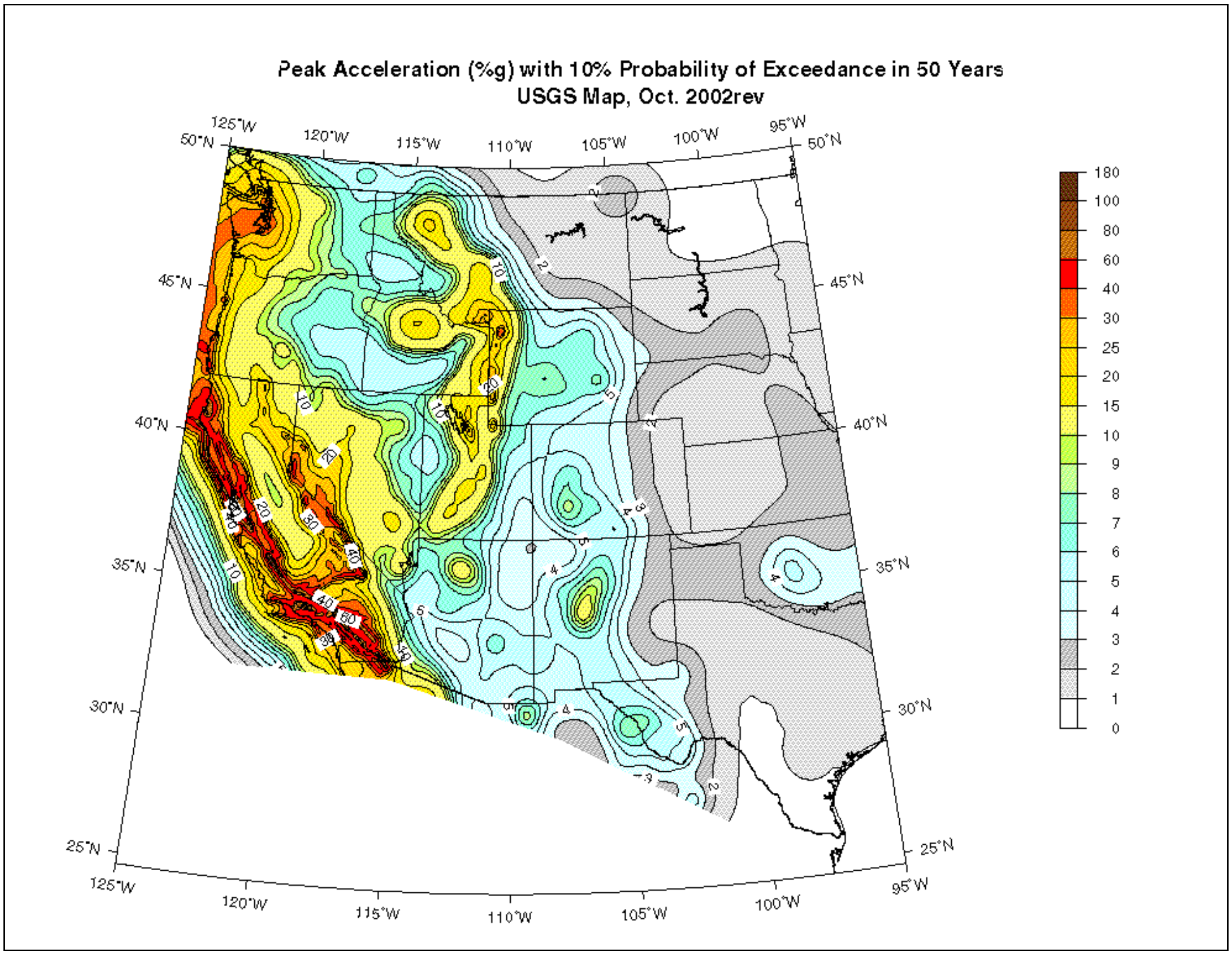
It is useful to note that, according to the USGS, a PGA of approximately 10.0 percent gravity is the approximate threshold of damage to older (pre-1965) dwellings or dwellings not made resistant to earthquakes. The 10 pg measure was chosen because, on average, it corresponds to the Modified Mercalli Intensities of VI to VII levels of threshold damage in California within 25 km of an earthquake epicenter. The earthquake hazard maps combine near and distant ground motions indiscriminately and should not be used for particular buildings (USGS, February 7, 2003).

Figure 7-6 provides more detailed view of the PGA map for Arizona. In this map, the probability of exceedance has been reduced to 2.0 percent, while the period has been kept constant at 50 years. Most of Arizona has a PGA of about 4.0 to 5.0 percent gravity (pg), with only the north-central and far southwestern parts of the state having a PGA of 10 pg or more. While these values are low in comparison with many parts of California, FEMA's Earthquakes Hazard Reduction Program has designated Arizona a "high risk" state for earthquakes (Bausch and Brumbaugh, May 23, 1996).

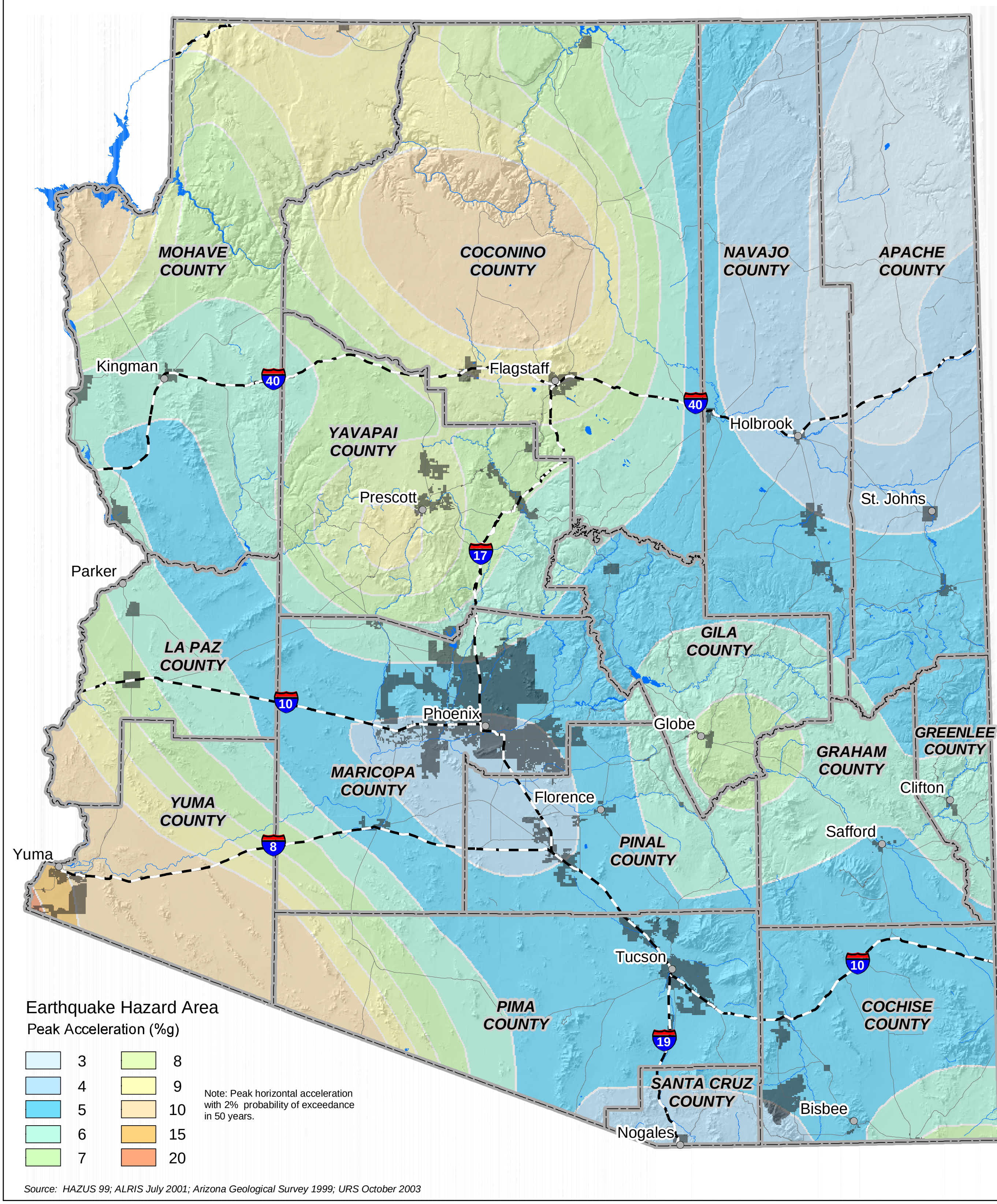
Yuma County, particularly the City of Yuma and nearby communities, face the highest risk from earthquakes in Arizona, as shown in Figure 7-6. Large portions of Yuma County have a PGA of 10.0 percent or higher (the approximate threshold of damage to older (pre-1965) dwellings or dwellings not made resistant to earthquakes). Furthermore, southwestern corner of Yuma County has a PGA of 20.0 percent, which is the greatest in the state. Earthquakes originating in southern California and northern Mexico cause ground shaking felt in Yuma at least once annually. Four major faults lie outside the state within 65 miles of Yuma: Imperial fault (28 miles), Cerro Prieto fault (45 miles), San Andreas fault (65 miles), and San Jacinto faults (65 miles). The stretch of the San Andreas fault nearest Yuma has not ruptured in over 300 years and is considered a likely area to experience a quake of M 8.0 or higher (which would cause catastrophic damage in the area). Compounding the earthquake risk, is the fact that large parts of the Yuma area will also be subject to soil liquefaction in the event of a major earthquake (Bausch and Brumbaugh, May 23, 1996).

The seismic hazard in Coconino County, particularly the area north of Flagstaff, is considered second only to that of the Yuma area. This area, which is also known as the Northern Arizona Seismic Belt (NASB), has a PGA of 15 pg, as shown in Figure 7-6. The area was the source of a number of large (M 6.0 or higher) earthquakes in the early-1900's and numerous smaller earthquakes since then. These events indicate that there is a 50.0 percent chance of a M 6.0 or higher earthquake during the next 30 years in the NASB (which would cause significant damage in the area). This event is considered to be the Maximum Probable Earthquake (MPE) for the Flagstaff community (Bausch and Brumbaugh, May 7, 1997).

Figure 7-5: Western United States Peak Ground Acceleration Map



Source: United States Geological Survey, April 2003



LEGEND

Interstate
City
County
County Seat
Highway
Major Stream
Lake

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December 2003

State of Arizona
Enhanced Hazard
Mitigation Plan

Figure 7-6

Peak Acceleration Map of Arizona

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A significant portion of Mohave County also has a PGA of 15 pg, as shown in Figure 7-6. The Hurricane Fault in northern Mohave County has the fastest displacement rate, longest length, and largest Maximum Credible Earthquake (MCE) of any Arizona fault, a M 7.75 event which would cause catastrophic damage. Historic earthquakes in the area have included the following: M 5.0 Hoover Dam Earthquake on May 4, 1939; M 6.4 Afton (California) earthquake on April 10, 1947; and the M 5.5-5.75 Fredonia earthquake on July 21, 1959. These quakes were felt over wide areas and caused numerous large rock falls and landslides. The location of three large dams in this area (Hoover Dam, Parker Dam, and Davis Dam) is also a factor when considering earthquake risk. Additional risk factors include neotectonic faults, growing population, and a high proportion of unreinforced masonry buildings (Bausch and Brumbaugh, July 30, 1997).

Portions of La Paz County are located within 100 miles of the San Andreas Fault system, resulting in a PGA of 10 pg, as shown in Figure 7-6. Historically, La Paz County has experienced strong earthquakes from California, including the M 7.1 Imperial Valley earthquake in May 1940, as well as smaller earthquakes from within the County. Portions of La Paz County also meet the criteria for liquefaction to occur (Bausch and Brumbaugh, August 31, 1997).

Parts of Yavapai County have a PGA of 9 pg, as shown in Figure 7-6. The county is subject to ground shaking from earthquakes originating on faults within the County and from nearby sources, such as the Hurricane Fault, Taroweap faults, and Northern Arizona Seismic Belt (NASB). Historically, earthquakes from these areas have caused significant ground shaking in Yavapai County. The County is also underlain by a series of faults that bisect it from northwest to southeast which have a potential for a M 7.25 earthquake (Bausch and Brumbaugh, June 28, 1997).

The risk of seismic hazard in the developed portions of Maricopa County is generally low, with PGA zones of 4-5 pg in most of metropolitan Phoenix. The southwestern corner of the county has elevated seismic risk where the PGA level increase up to 15 pg, although this region is largely uninhabited. The seismic risk to the Phoenix areas is elevated, however, due to the large and growing population, existence of some high rise buildings, predominance of unreinforced masonry buildings, and the lack of earthquake awareness among its population (Bausch and Brumbaugh, June 13, 1994).

The rate of seismicity in the Phoenix area has historically been low, with the area's most recent quakes originating in Cave Creek in 1974 (M 2.5 and M 3.0). However, the area has been impacted by major quakes in southern California and northern Mexico, including the 1887 Sonoran quake (M 7.2) which caused ground shaking and triggered rock falls in the Phoenix area. The largest impact of an earthquake on the Phoenix metropolitan area would be the economic impact from a catastrophic southern California earthquake, which would disrupt approximately 60.0 percent of Arizona's fuel and 90.0 percent of Arizona's food goods. The Phoenix area could also be significantly affected by a major quake in the Yuma or Northern Arizona Seismic Belt (NASB). A repeat of the 1887 earthquake would result in significant damage to Arizona's population centers, particularly where development is located on alluvial plains and steep slopes, which is the case in much of the Phoenix area. The Sugarloaf and Horseshoe faults are the nearest mapped potentially active faults, both approximately 40 miles northeast of the Phoenix area. A M 6.75 is the largest credible earthquake that occur on these faults which would result in rock falls, dam failure, liquefaction, destructive resonance in reinforced concrete buildings three to four stories in height, and ground motion sufficient to cause damage in other structures (Bausch and Brumbaugh, June 13, 1994).

It should also be noted that although the small earthquakes that commonly occur in Arizona are of low seismic risk to buildings, the repeated shaking could eventually cause structural damage. Small earthquakes may also trigger in unstable areas landslides and boulders rolling off mountain slopes (Jenny and Reynolds, 1989).

7.3.4.4 Warning Time

Earthquake forecasts are similar to weather forecasts in that earthquake forecasts declare that a temblor of a specified magnitude has a certain probability of occurring within a given time, not that one will definitely strike. Because quakes tend to occur in clusters that strike the same area within a limited time period, scientists are able to make earthquake forecasts. The largest quake in a cluster is called the mainshock, those before it are called foreshocks, and those after it are called aftershocks (USGS, 1995).

Predicting earthquakes days in advance is not expected to be possible anytime soon. However, an early warning system that will alert southern California residents seconds before a temblor begins is under development. The system, Earthquake Alarm System (ElarmS), could use an existing system (TriNet) in southern California to issue a warning a few to tens of seconds ahead of damaging ground motion. ElarmS use the frequency content of the P-wave arrival to determine earthquake magnitude, which allows magnitude estimation and could provide a warning tens of seconds before damaging ground motion occurs. This could be sufficient time for people to take cover beneath a table or shut off gas lines and water mains (Allen and Kanamori, May 5, 2003).

While advance prediction of earthquakes may not immediately be possible, there are three major networks in the U.S. to monitor earthquakes, each operated largely by the United States Geological Survey:

- The Advanced National Seismic System (ANSS) will be a nationwide network of at least 7,000 shaking measurement system on the ground and on buildings. The system will make it possible to provide emergency response personnel with real-time earthquake information, engineers with information about building and site response, and scientists with high-quality data to understand earthquakes (USGS, May 2000).

- The United States National Seismic Network (USNSN) provides uniform coverage of the U.S. and integrates data from its own stations and the more than 2,500 seismograph stations in regional networks of the United States. Regional networks provide information about earthquakes to the USGS National Earthquake Information Center (NEIC) in Colorado, which serves as a national point of contact for distributing earthquake information (USGS, March 14, 2003).

- The National Strong-Motion Program (NSMP) has the primary federal responsibility for recording damaging earthquakes in the United States on the ground and in man-made structures in densely urbanized areas in order to improve public earthquake safety. The program maintains a national cooperative instrumentation network, a national data center, and a supporting strong-motion data analyses and research center in support of this responsibility (USGS, November 14, 2002).

7.3.5 Extreme Heat

7.3.5.1 Nature

Extreme summer heat is the combination of very high temperatures and exceptionally humid conditions. If such conditions persist for an extended period of time, it is called a heat wave (FEMA, 1997). Heat stress can be indexed by combining the effects of temperature and humidity, as shown in Table 7-9. The index estimates the relationship between dry bulb temperatures (at different humidities) and the skin's resistance to heat and moisture transfer. The higher the temperature or humidity, the higher the apparent temperature. The major human risks associated with extreme heat are as follows:

- Heatstroke: Considered a medical emergency, heatstroke is often fatal. It occurs when the body's responses to heat stress are insufficient to prevent a substantial rise in the body's core temperature. While no standard diagnosis exists, a medical heatstroke condition is usually diagnosed when the body's temperature exceeds 105°F due to environmental temperatures. Rapid cooling is necessary to prevent death, with an average fatality rate of 15 percent even with treatment.

- Heat Exhaustion: While much less serious than heatstroke, heat exhaustion victims may complain of dizziness, weakness, or fatigue. Body temperatures may be normal or slightly to moderately elevated. The prognosis is usually good with fluid treatment.

- Heat Syncope: This refers to sudden loss of consciousness and is typically associated with people exercising who are not acclimated to warm temperatures. Causes little or no harm to the individual.
- Heat Cramps: May occur in people unaccustomed to exercising in the heat and generally ceases to be a problem after acclimatization.

Table 7-9: Heat Index and Disorders

Danger Category		Heat Disorders	Apparent Temperatures (°F)
IV	Extreme Danger	Heatstroke or sunstroke imminent.	>130
III	Danger	Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and physical activity.	105-130
II	Extreme Caution	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and physical activity.	90-105
I	Caution	Fatigue possible with prolonged exposure and physical activity.	89-90

Source: FEMA, 1997; NWS, 1997.

In addition to affecting people, severe heat places significant stress on plants and animals. The effects of severe heat on agricultural products, such as cotton, may include reduced yields and even loss of crops (Brown and Zeiher, 1997). Similarly, cows may become overheated, leading to reduced milk production and other problems. (Garcia, September 2002).

7.3.5.2 History

Extreme summer heat occurs with some regularity in the U.S. and in other countries. Major historic events have included the following:

- In 1980, summer temperatures reached all time highs in Central and Southern States, with over 1,700 deaths identified as heat related (FEMA, 1997).
- In July 1995, apparent temperatures in the Central Plains were over 120°F and a significant portion of the Eastern States had apparent temperatures of 105-120°F. An estimated 670 deaths occurred as a result, some 375 in Chicago alone. Low-income and elderly people were particularly at risk from the heat due to a lack of air conditioning. Controlled power outages also occurred due to excessive demand and water supplies were very low. In addition, the heat resulted in the death of tens of millions of cattle and poultry throughout the Midwest (FEMA, 1997).
- In July and August 2003, a heat wave across Europe caused thousands of deaths, including at least 11,000 in France alone. Again, a high proportion of the victims were elderly (Brock, September 14, 2003).

While summer temperatures in Arizona regularly reach levels that would be considered extreme in many parts of the country, a total of only 11 extreme heat events affecting Arizona were identified, as shown in Table 7-3, none of which resulted in a disaster/emergency declaration. No fatalities, injuries, or damages for specific events were recorded, although Arizona is estimated to have 35-50 deaths annually from excessive summer heat (Arizona Department of Health Services, June 18, 2001). Specific extreme high temperature events in Arizona include the following:

- The record in Phoenix was set on June 26, 1990 at Sky Harbor Airport, which reached 122°F, forcing closure of the airport for several hours.

- The state's record temperature was established on June 29, 1999, when the temperature reached 128°F in Lake Havasu City.

Triple digit temperatures (100+°F) are regularly experienced in Arizona and have been recorded in Phoenix and Yuma in the months of March to October, as shown in Table 4-2. Tucson has also experienced such temperatures from April to October.

7.3.5.3 Probability and Magnitude

The probability and frequency of heat hazards may be characterized by a heat index using temperature and humidity readings. Such an index has been developed for the entire U.S. and the Arizona portion is shown in Figure 7-7. The map was prepared using hourly readings between 2 PM and 5 PM for June, July, and August (based on the assumption that the annual maximum temperature and relative humidity occurs during summer afternoons). The data was used to conduct a frequency analysis from which the heat index map was prepared (with a 5.0 percent chance of exceedance in any given year).

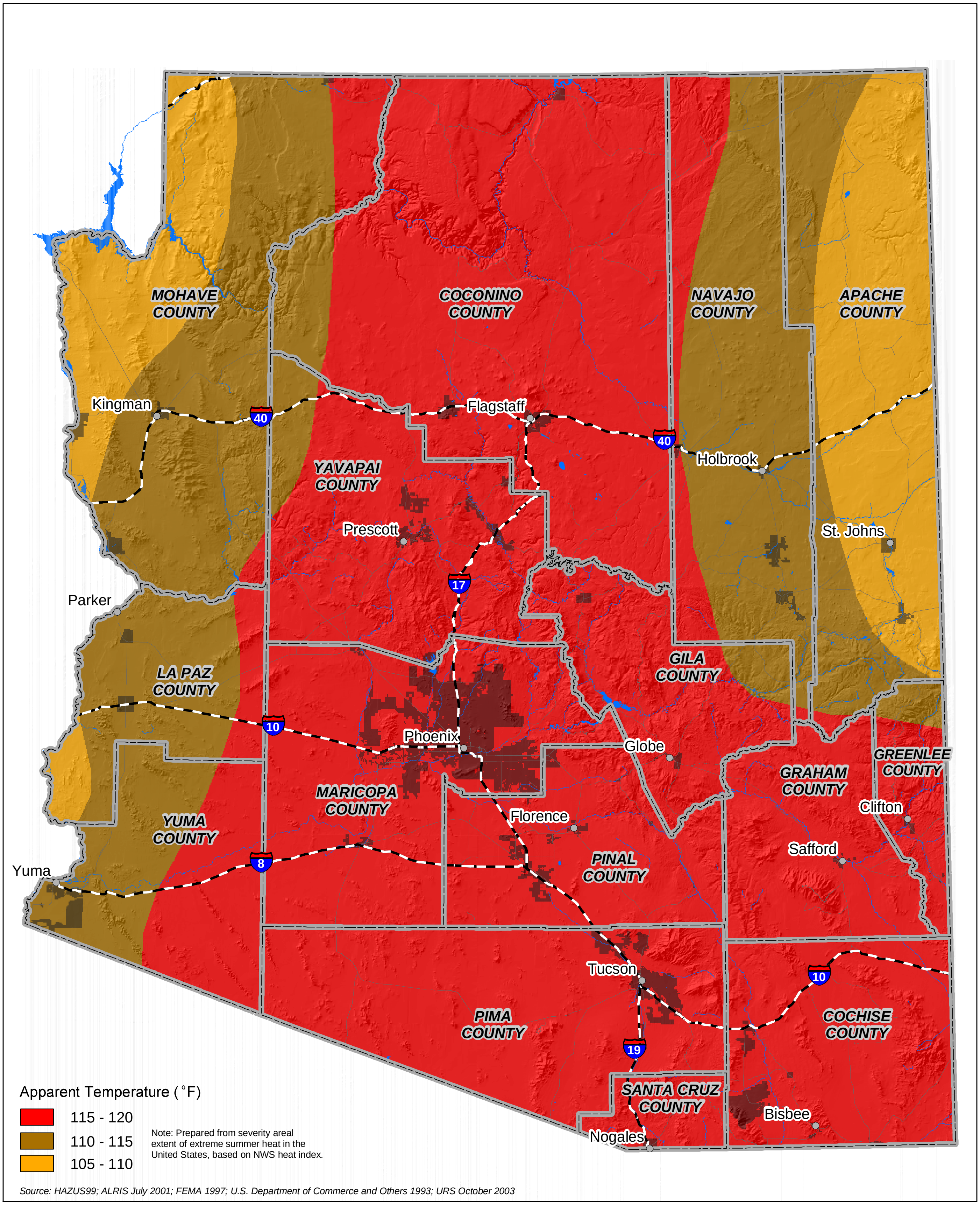
As shown, most of Arizona has a very high probability of reaching temperatures that are classified as dangerous or even extremely dangerous according to the heat index in Figure 7-7. This is in-line with the high summer temperatures and humidity levels that are regularly experienced throughout Arizona (see Table 4-1, Table 4-2, and Table 4-3).

7.3.5.4 Warning Time

It is a well-known fact that Arizona regularly experiences months of high summer temperatures and relatively high humidity levels (caused by the monsoons). As a result, extreme summer temperatures are hardly surprising and the warning time could be considered on the order of months.

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

The fact that unusual and potentially deadly hot weather events occur in Arizona led to the launch of a heat warning service in 2001. The service is a joint effort by the National Weather Service (NWS), Arizona Department of Health Services (ADHS), Salt River Project (SRP), and Arizona Department of Commerce (ADOC). The service will warn the public of danger up to 2 ½ days in advance via press releases and will remind people to take precautions to prevent heat-related illnesses (Arizona Department of Health Services, June 18, 2001).



LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-7

Summer Heat Severity in Arizona

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ARIZONA EMERGENCY MANAGEMENT

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7.3.6 Flood

7.3.6.1 Nature

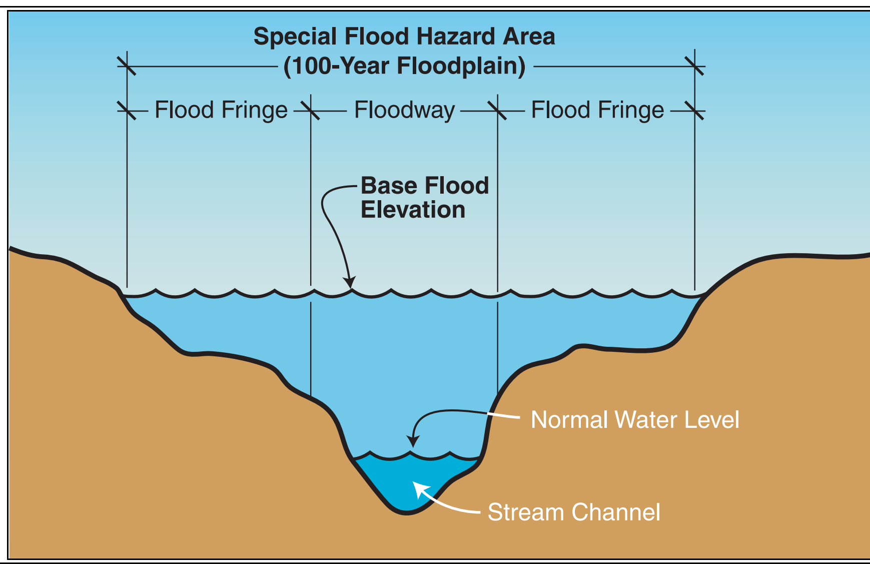
Flooding is the accumulation of water within a water body (e.g., stream, river, lake, reservoir) and the overflow of excess water onto adjacent floodplains. As illustrated in Figure 7-8, floodplains are lowlands, adjacent to water bodies that are subject to recurring floods. Floods are natural events that are considered hazards only when people and property are affected. Nationwide, hundreds of floods occur each year, making it one of the most common hazards in all 50 states and U.S. territories (FEMA, 1997).

There are a number of categories of floods in the U.S., including the following:

- Riverine flooding, including overflow from a river channel, flash floods, alluvial fan floods, ice-jam floods, and dam break floods;
- Local drainage or high groundwater levels;
- Fluctuating lake levels;
- Coastal flooding, including storm surges;
- Debris flows; and
- Subsidence.

The most common type of flooding event is riverine flooding, also known as overbank flooding. Riverine floodplains range from narrow, confined channels in the steep valleys of mountainous and hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, and land use characteristics. In steep valleys, flooding is usually rapid and deep, but of short duration, while flooding in flat areas is typically slow, relatively shallow, and may last for long periods of time.

Figure 7-8: Floodplain Definition Sketch



Source: FEMA, August 2001.

The cause of flooding in large rivers is typically prolonged periods of rainfall from weather systems covering large areas (e.g., tropical storms). These systems may saturate the ground and overload the rivers and reservoirs in numerous smaller basins that drain into larger rivers. Localized weather systems (e.g., thunderstorms), may cause intense rainfall over smaller areas, leading to flooding in smaller rivers and streams. Annual spring floods, due to the melting of snowpack, may affect both large and small rivers and areas.

While there is no sharp distinction between riverine floods, flash floods, alluvial fan floods, ice jam floods, and dam-break floods, these types of floods are widely recognized and may be helpful in considering the range of flood risk and appropriate responses:

- Flash flood is a term in wide use by experts and the general population, but there is no single definition or clear means of distinguishing flash floods from other riverine floods. Flash floods involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage that includes the tearing out of trees, undermining of buildings and bridges, and scouring new channels. The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Dam failure and ice jams may also lead to flash flooding. Urban areas are increasingly subject to flash flooding due to the removal of vegetation, covering of ground cover with impermeable surfaces, and construction of drainage systems. Flash floods are a significant hazard in Arizona.
- As indicated by the name, alluvial fan floods occur in the deposits of rock and soil that have eroded from mountainsides and accumulated on valley floors in the pattern of a fan. Alluvial fan floods often cause greater damage than straightforward riverine flooding due to the high velocity of the flow, amount of debris, and broad area affected. Alluvial fan flooding is most prevalent in arid western states, such as Arizona. Human activities may exacerbate flooding and erosion on alluvial fans via increased velocity along roadway acting as temporary drainage channels or changes to natural drainage channels from fill, grading, and structures. Alluvial fan floods are a significant hazard in Arizona, particularly in urbanized areas. Floods on alluvial fans are dangerous because they are unpredictable. Channels may migrate quickly, for example, and the water flow often travels at high velocity–much higher than usually found in rivers or streams. This velocity is usually much more of a problem than the depth of the flow. Such action on alluvial fans is often characterized as "sheet flow" because of the high speed and shallow depth. In contrast to other flood hazards (i.e. riverine situations), FEMA puts an average velocity on the Flood Insurance Rate Map (FIRM) when mapping an alluvial fan to draw attention to the additional hazard posed by velocity.
- Ice jam floods are primarily a function of the weather and are most likely to occur where the channel slope naturally decreases, culverts freeze solid, reservoir headwaters, natural channel constructions (e.g., bends and bridges), and along shallows. Ice jam floods are not considered a significant hazard in Arizona.

Dam break floods may occur due to structural failures (e.g., progressive erosion), overtopping or breach from flooding, or earthquakes. Dam breaks or failures are examined in detail in Section 7.3.1. The risk from dam failures is a significant hazard in Arizona.

Local drainage floods may occur outside of recognized drainage channels or delineated floodplains due to a combination of locally heavy precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and increased surface runoff. Such events frequently occur in flat areas, particularly during winter and spring in areas with frozen ground, and also in urbanized areas with large impermeable surfaces. High groundwater flooding is a seasonal occurrence in some areas, but may occur in other areas after prolonged periods of above-average precipitation. Losses associated with local drainage are most significant when they occur with other hazards described in this document, such as widespread flooding and thunderstorms; therefore, they are not analyzed as a distinct hazard.

Many urban areas that have historically been flood prone have been removed from the floodplain through the application of two construction types: (1) flood control dams, which reduce peak discharges; and, (2) levees, which redirect floods away from areas that would otherwise be inundated. Much of the Phoenix metropolitan area, for example, is protected by these systems.

7.3.6.2 History

Floods occur in all 50 US states and territories, with an estimated 4 percent of the total area of the United States subject to the 1-percent annual chance floodplain. An estimated nine million US households and $390 billion in property are at risk within the 1-percent annual chance floodplain. Nationwide damage from flooding has increased from $902 billion annually during the period 1916-1950 to $2.15 billion annually, an increase of almost two-and-a-half times. The worst flood disaster in US history was caused by a series of storms from April to September of 1993 in the Upper Mississippi Basin. There were 38 to 47 flood-related deaths and damage was estimated at $12 to $16 billion, including $4 to $5 billion in agricultural losses (FEMA, 1997).

Flash floods are the top weather-related killer in the United States, resulting in about 150 deaths every year. Most, if not all, of these fatalities could have been avoided if those involved would have recognized the dangers of flash floods and taken a few simple actions to protect themselves (National Weather Service Flagstaff).

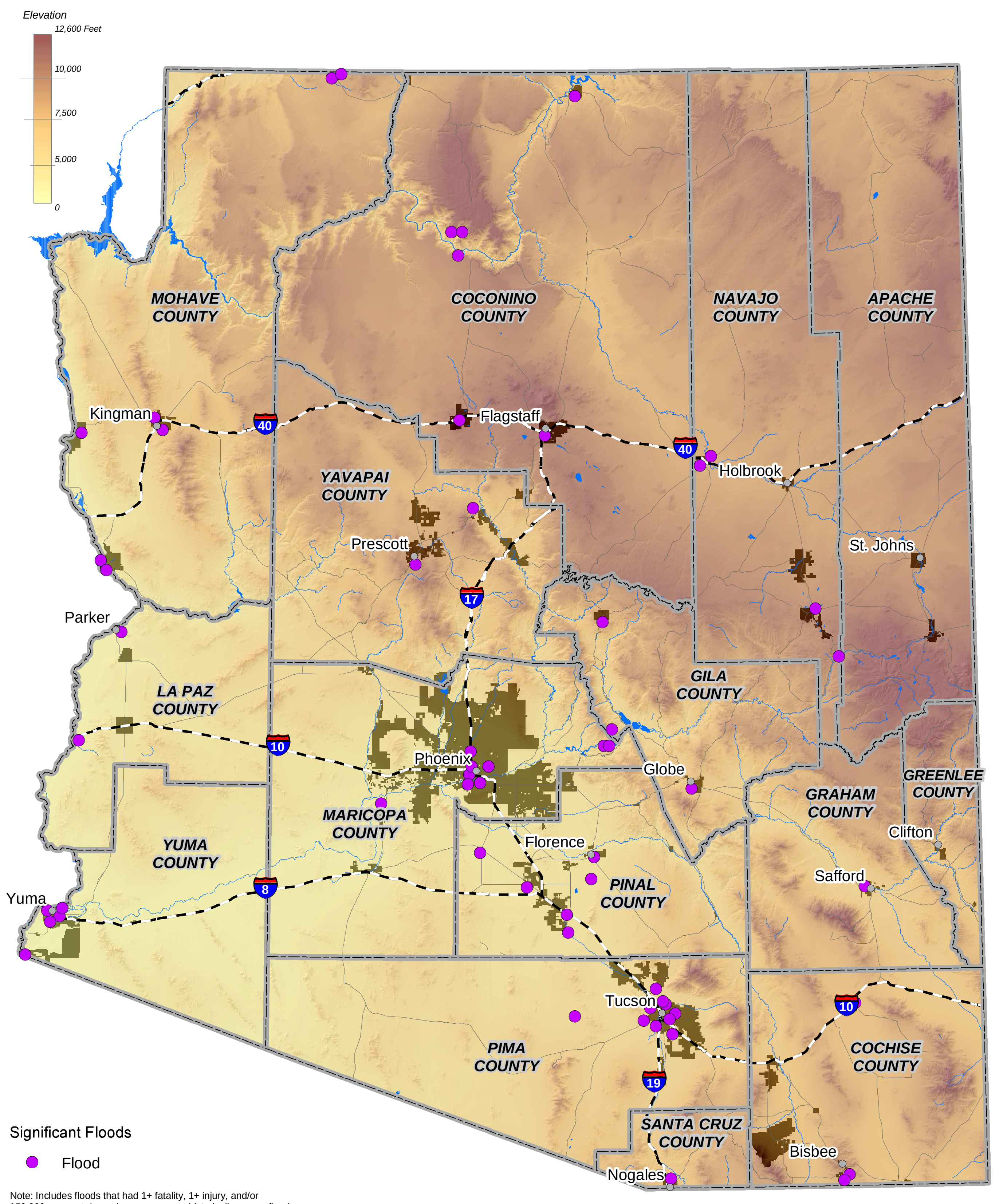
Arizona has experienced 40 flooding incidents of sufficient magnitude to prompt Presidential or Gubernatorial disaster declarations, as shown in as shown in Table 7-3, nearly double the next highest number of declarations which is for wildfires. In addition, there were 63 undeclared significant flood events. The combined flood total of 103 declared flood and undeclared events are reported to have killed 35 persons and injured 250. Furthermore, these events are reported to have caused nearly $1.3 billion dollars in damages, by far the most of any hazard in Arizona. No part of the state is free from the threat of flooding, as shown in Figure 7-9. A close correlation is evident between the locations of significant floods and urbanized areas of the state.

Flooding is clearly a major hazard in Arizona, where the following three seasonal atmospheric conditions tend to trigger flooding events:

- **Tropical Storm Remnants**: The worst flooding tends to occur when the remnants of a tropical storm enter the state. These events occur infrequently (i.e. every ten ears or so), mostly in the early autumn, but when they do occur the storms bring intense precipitation over large regions causing severe flooding
- **Winter Rains**: Winter brings the threat of low intensity; but long duration rains covering large areas that cause extensive flooding and erosion, particularly when combined with snowmelt.
- **Summer Monsoons**: A third atmospheric condition that brings flooding to Arizona is the annual summer monsoon. In mid to late summer the monsoon winds bring humid subtropical air into the state. Solar heating triggers afternoon thunderstorms that can be devastating. As a result of too much rain, in too small an area, in too short a time, flash flooding may result.

Arizona has been subject to multiple examples of each of the above flood types. The following are a few representative examples:

- The summer of 1990 brought some of the worst and most extensive flooding experienced in Arizona, due primarily to a series of flash flooding events. Between July 8 and 24, 1990, Arizona experienced a series of severe thunderstorms caused by an unusually strong monsoon season that exceeded annual and individual storm event average, resulting in heavy rain, high winds, flash flooding and damage to Gila, Mohave, Pima and Yavapai Counties. On July 27, 1990, Governor Rose Mofford declared a state of emergency. Additional storms damaged parts of Pinal and Graham counties between August 12 and 21. From August 30 to September 5, 1990 a final series of storms impacted parts of Coconino, Maricopa, and Yavapai Counties and the Havasupai and Hualapai Indian Reservations. Sky Harbor International Airport in Phoenix reported over seven inches of rain by the end of the monsoon season, more than two inches above average. Other reporting stations experienced even greater precipitation amounts, sometimes falling in extreme bursts. These storms led to the death of three persons, as well as extensive reports of flash flood and wind damages. Damages to public facilities alone reached nearly $6.6 million, not including those on Arizona Indian Reservations (FEMA, January 1992).



Note: Includes floods that had 1+ fatality, 1+ injury, and/or $50,000+ property/crop damage, or were historically severe floods.

Source: *HAZUS99; ALRIS July 2001; DEMA March 2003; NCDC March 2003; URS October 2003*

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-9

Significant Floods in Arizona

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- During January and February 1993, winter rain flooding damage occurred from winter storms associated with the El Nino phenomenon. These storms flooded watersheds throughout Arizona by dumping excessive rainfall amounts that saturated soils and increased runoff. Warm temperature snowmelt exacerbated the situation over large areas. Erosion caused tremendous damage and some communities along normally dry washes were devastated. Stream flow velocities and runoff volumes exceeded historic highs. Many flood prevention channels and retention reservoirs were filled to capacity, so water was diverted to the emergency spillways or the reservoirs were breached, causing extensive damage in some cases (e.g., Painted Rock Reservoir spillway). Ultimately, the President declared a major federal disaster that freed federal funds for both public and private property losses statewide. Damages were widespread and significant, impacting over 100 communities. Total public and private damages exceeded $400 million, and eight deaths and 112 injuries were reported to the Red Cross (FEMA, April 1, 1993; ADEM, March, 1998).
- Associated primarily with summer monsoons, flash floods can travel miles beyond the storm that generated them and catch people by surprise. On August 12, 1997 twelve hikers were caught in a deadly flash flood as a 10-30 foot wall of water rushed through Lower Antelope Canyon. The hikers did not recognize the flood danger until it was too late, probably because the storm that caused the flood occurred several miles away. Only one-month later two hikers were killed and one injured by a flash flood as they were crossing Phantom Creek in the Grand Canyon National Park. Again, the hikers were caught off guard, probably because the storm that caused the flood occurred several miles north of the flash flood site (National Weather Service Flagstaff).
- It is also important to note that in addition to affecting people, floods may severely affect livestock and pets. Such events may require the emergency watering/feeding, shelter, evacuation, and event burying of animals, such as during the floods in Maricopa County in the 1980's and La Paz County in 2001 (Lanman, May 27, 2003).

A measure of the seriousness and location of floods in Arizona is the number of National Flood Insurance Program (NFIP) losses and payments. During the period 1978 to 2002, there were 3,262 losses and nearly $22.5 million in payments, as shown in Table 7-10, Maricopa County has the most losses and payments at, respectively, 1,750 and $8.9 million. Pima County has the second highest number of losses at 276, with $1.9 million in payments. Greenlee County has only 149 losses, but the second highest payments at $2.4 million. Other counties with payments over $1.0 million are Pinal, Santa Cruz, Yavapai, and Yuma.

In 1968, Congress created the NFIP in response to the rising cost of taxpayer funded disaster relief for flood victims and the increasing amount of damage caused by floods. The Mitigation Division, a component of the Federal Emergency Management Agency (FEMA) manages the NFIP, and oversees the floodplain management and mapping components of the Program.

Nearly 20,000 communities across the United States and its territories participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities.

The NFIP Community Rating System (CRS) was implemented in 1990 as a program to recognize and encourage community floodplain management activities that exceed minimum NFIP standards. The National Flood Insurance Reform Act of 1994 codified the CRS in the NFIP. Under the CRS, flood insurance premium rates are adjusted to reflect the reduced flood risk resulting from community activities that meet the three goals of the CRS: (1) reduce flood losses; (2) facilitate accurate insurance rating; and (3) promote the awareness of flood insurance.

Table 7-10: National Flood Insurance Program (NFIP) Loss Statistics in Arizona by County, 1978-2002

County	Losses	Payments
Apache	2	$ 3,180.96
Cochise	48	$ 161,938.05
Coconino	87	$ 583,417.01
Gila	42	$ 290,380.45
Graham	30	$ 166,478.94
Greenlee	149	$ 2,357,622.19
La Paz	70	$ 753,345.78
Maricopa	1,750	$ 8,877,559.13
Mohave	114	$ 673,631.14
Navajo	87	$ 808,721.24
Pima	276	$ 1,895,580.61
Pinal	101	$ 1,883,144.44
Santa Cruz	131	$ 1,022,378.79
Yavapai	234	$ 1,858,065.25
Yuma	141	$ 1,147,777.62
Total	**3,262**	**$ 22,483,221.60**

Source: FEMA, May 16, 2003; URS, October 2003.

Flood damage is reduced by nearly $1 billion a year through partnerships with NFIP and CRS communities, the insurance industry, and the lending industry. Buildings constructed in compliance with NFIP building standards also suffer approximately 80 percent less damage annually than those not built in compliance. Further, every $3 paid in flood insurance claims saves $1 in disaster assistance payments.

The NFIP is self-supporting for the average historical loss year, which means that operating expenses and flood insurance claims are not paid for by the taxpayer, but through premiums collected for flood insurance policies. The Program has borrowing authority from the U.S. Treasury for times when losses were heavy, however, these loans have been paid back with interest.

To obtain secured financing to buy, build, or improve structures in Special Flood Hazard Areas (SFHA's), flood insurance must be purchased. Lending institutions that are federally regulated or federally insured must determine if the structure is located in a SFHA and must provide written notice requiring flood insurance.

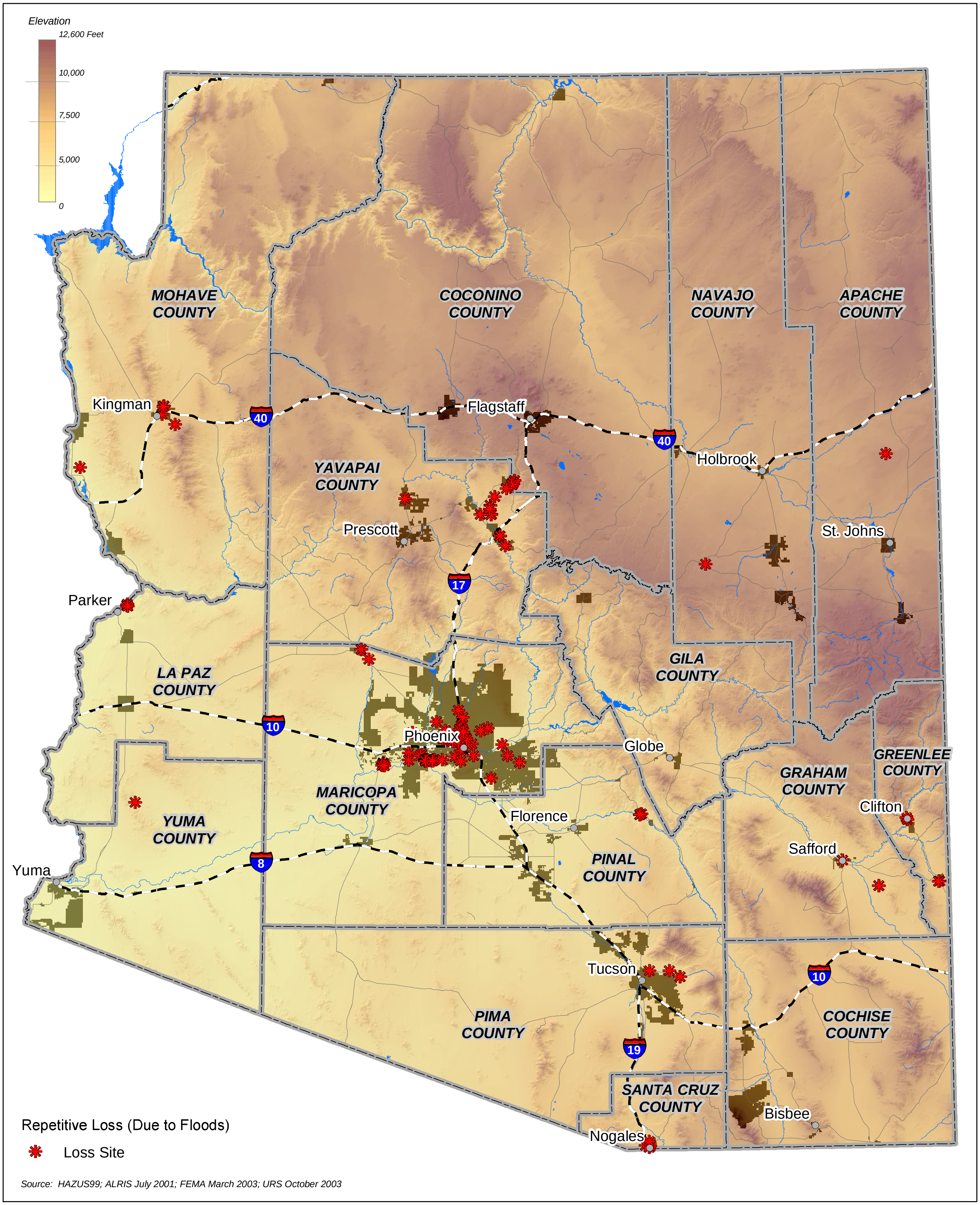
Flood insurance is available to any property owner located in a community participating in the NFIP. All areas are susceptible to flooding, although to varying degrees. In fact, 25 percent of all flood claims occur in low-to-moderate risk areas. (FEMA, 2003)

Currently, 28,206 eligible homeowners in Arizona have taken advantage of the NFIP program, as shown through Table 7-11. It should be noted that only a minority of property owners in floodplains actually purchase flood insurance, therefore the actual financial loss experienced locally is probably much greater than indicated here.

Table 7-11: National Flood Insurance Program (NFIP) Policy Holders in Arizona by County, 2002	
County	**Policies In Force**
Apache	50
Cochise	1,106
Coconino	603
Gila	384
Graham	121
Greenlee	84
La Paz	251
Maricopa	15,771
Mohave	1,906
Navajo	286
Pima	4,809
Pinal	435
Santa Cruz	397
Yavapai	1,327
Yuma	676
Total	**28,206**

Source: FEMA, May 16, 2003; URS, December 2003.

According to FEMA records, there were 172 identified Repetitive Loss (RL) properties in Arizona, with a total of $4.8 million in associated total payments (building and contents value), as shown in Table 7-12 and displayed by location in Figure 7-10. Maricopa County clearly dominates the state with 120 repetitive loss properties and $3.2 million in total payments. Yavapai County is the next largest, with seven properties and $0.4 million in total payments.



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State of Arizona
Enhanced Hazard
Mitigation Plan

Figure 7-10

Repetitive Loss (RL) Properties in Arizona

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Table 7-12: Flood Repetitive Losses (RL) in Arizona by County			
County	**No. of Properties**	**Losses**	**Payments**
Apache	1	3	$ 7,280.96
Cochise	-	-	$ -
Coconino	7	15	$ 183,152.68
Gila	-	-	$ -
Graham	3	9	$ 47,088.30
Greenlee	6	12	$ 229,546.71
La Paz	3	7	$ 184,904.04
Maricopa	120	270	$ 3,198,468.23
Mohave	4	9	$ 49,312.96
Navajo	3	6	$ 60,678.04
Pima	4	9	$ 146,442.59
Pinal	3	6	$ 137,508.28
Santa Cruz	3	7	$ 85,492.15
Yavapai	14	31	$ 428,615.42
Yuma	1	2	$ 5,525.89
Total	**172**	**386**	**$ 4,764,016.25**

Source: FEMA, May 7, 2003; URS, October 2003.

7.3.6.3 Probability and Magnitude

Floods are described in terms of their extent (including the horizontal area affected and the vertical depth of floodwaters) and the related probability of occurrence. Flood studies use historical records to determine the probability of occurrence for different extents of flooding. The probability of occurrence is expressed in percentages as the chance of a flood of a specific extent occurring in any given year.

The most widely adopted design and regulatory standard for floods in the United States is the 1-percent annual chance flood and this is the standard formally adopted by FEMA. The 1-percent annual flood, also known as the base flood, has a 1 percent chance of occurring in any particular year. It is also often referred to as the "100-year flood" since its probability of occurrence suggests it should only reoccur once every 100 years (although this is not the case in practice). Experiencing a 100-year flood does not mean a similar flood cannot happen for the next 99 years; rather it reflects the probability that over a long period of time, a flood of that magnitude should only occur in 1 percent of all years.

Smaller floods occur more often than larger (deeper and more widespread) floods. Thus, a "10-year" flood has a greater likelihood of occurring than a "100-year" flood. Table 7-13 shows a range of flood recurrence intervals and their probabilities of occurrence.

Table 7-13: Flood Probability Terms	
Flood Recurrence Intervals	**Percent Chance of Occurrence Annually**
10 year	10.0%
50 year	2.0%
100 year	1.0%
500 year	0.2%
Source: FEMA, August 2001.	

Figure 7-11 displays the 100-Year 24-hour Probable Maximum Precipitation (PMP) in Arizona. Note that this map displays an event with a 1 percent chance of being exceeded in any year, not an event that is expected to occur once every 100 years. The map was developed using multiple methods, including judgments based on record storms and related meteorological processes, with the results of the studies considered estimates because changes are likely to occur as understanding increases. The studies assumed that storm records for the preceding 80 years were representative and no allowance was made for climate change.

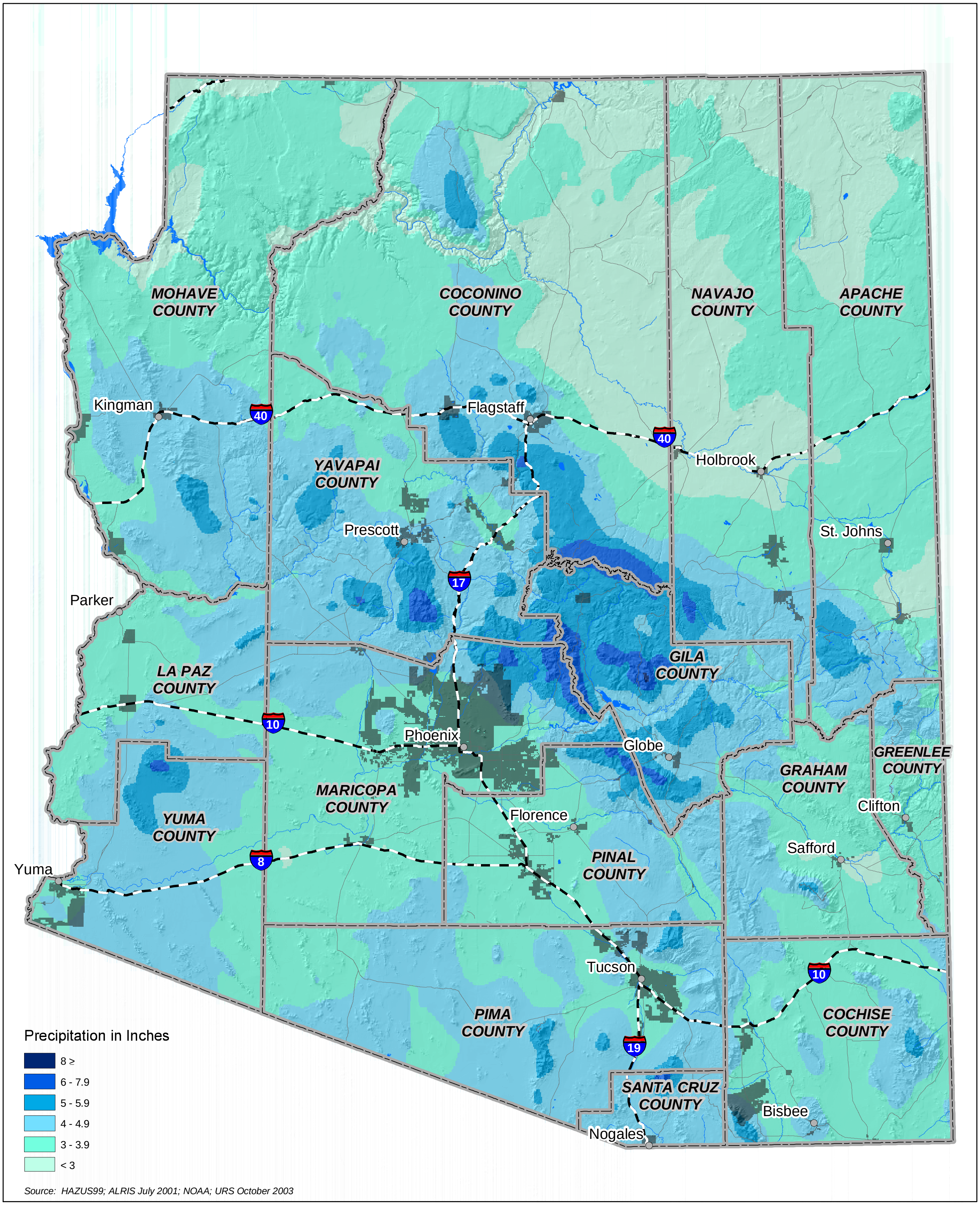
Figure 7-12 highlights the known 100-year flood plain areas within most of the State as determined by FEMA. Note that Digital Flood Insurance Rates (DFIRMs) are not yet available for Apache, Graham, La Paz, Pinal, and Yuma Counties. The total area within the 100-year floodplain is shown by county in Table 7-14, as well as the amount within urban boundaries.

Table 7-14: 100-Year Floodplains In Arizona by County

County	Total Area in Square Miles	Area Within 100-Year Floodplain			
		Total		Within Urban Boundaries	
		Sq. Mi.	Percent	Sq. Mi.	Percent
Apache	11,216.0	NA	NA	NA	NA
Cochise	6,215.0	339.0	5.5%	6.8	0.1%
Coconino	18,644.0	91.0	0.5%	3.8	0.0%
Gila	4,792.0	50.0	1.0%	1.7	0.0%
Graham	4,649.0	NA	NA	NA	NA
Greenlee	1,836.0	54.0	2.9%	0.9	0.0%
La Paz	4,517.0	NA	NA	NA	NA
Maricopa	9,222.0	519.0	5.6%	158.0	1.7%
Mohave	13,480.0	478.0	3.5%	11.5	0.1%
Navajo	9,952.0	236.0	2.4%	16.5	0.2%
Pima	9,184.0	380.0	4.1%	63.3	0.7%
Pinal	5,371.0	NA	NA	NA	NA
Santa Cruz	1,236.0	54.0	4.4%	2.6	0.2%
Yavapai	8,125.0	200.0	2.5%	23.1	0.3%
Yuma	5,523.0	NA	NA	NA	NA
Total	**113,962.0**	**2,401.0**	**2.1%**	**288.2**	**0.3%**

Note: Floods may still occur outside of identified flood prone areas.

Source: FEMA, April 22, 2003; URS, October, 2003.



LEGEND

Interstate
City
County
County Seat
Highway
Major Stream
Lake

N

0 25 50
Miles

State of Arizona
Enhanced Hazard
Mitigation Plan

Figure 7-11

100-Year 24-Hour Probable Maximum Precipitation in Arizona

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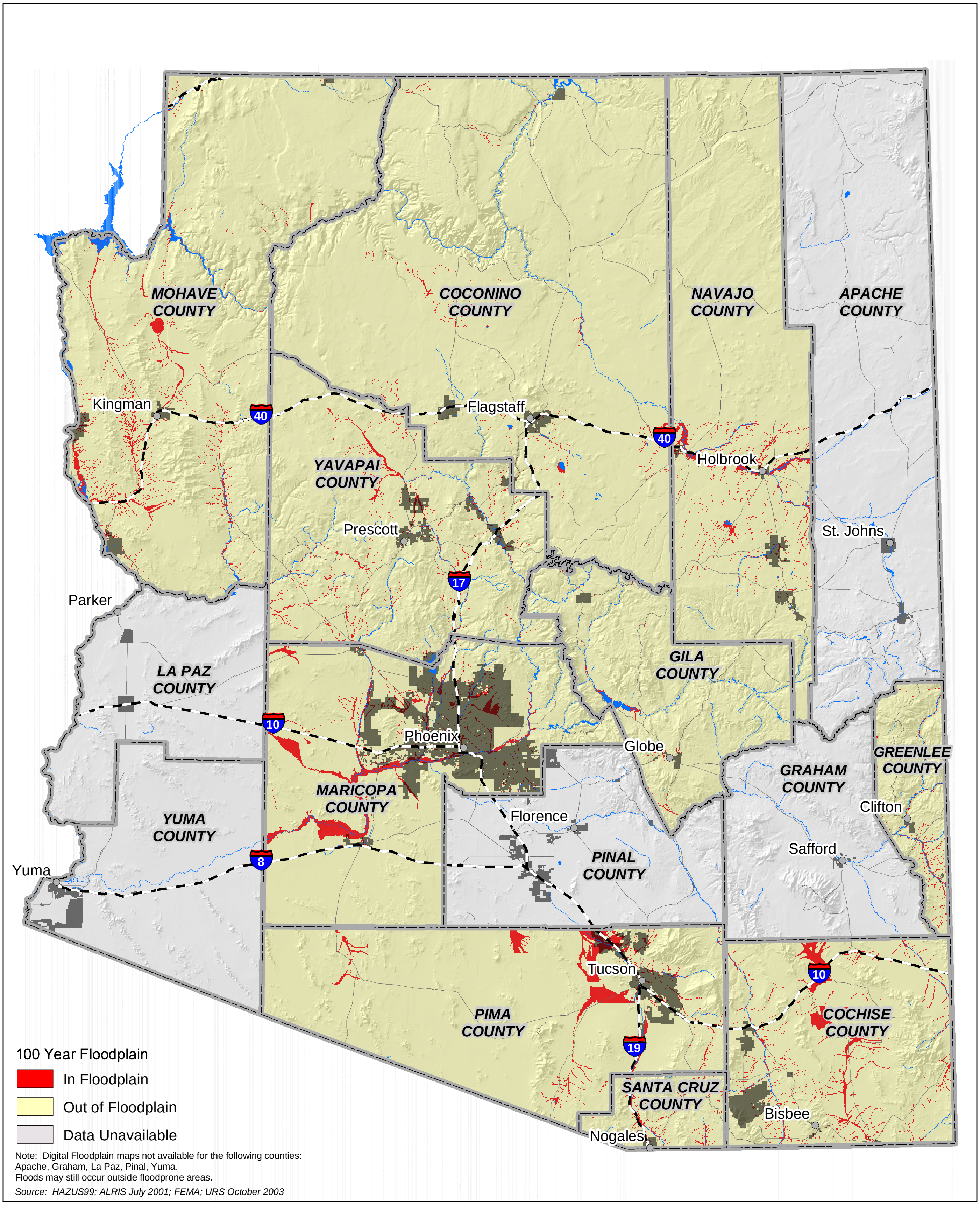
December 2003



LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

0 25 50
Miles

N

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-12

100-Year Flood Hazard Zones in Arizona

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ARIZONA EMERGENCY MANAGEMENT

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Overall, the probability of floods in Arizona is very high, with the probability typically greater in the southern deserts than in the northern highlands. In the northern plateau region, runoff is funneled into defined river systems, drainage channels and canyons. Communities in northern Arizona are generally unaffected by floods because they are placed above the drainage flow. Further, northern Arizona has large areas of permeable limestone and volcanic topography where rainfall rapidly percolates into the ground. By contrast, in the desert basins of southern Arizona, runoff channels are not as well defined. Over 90 percent of Arizona's population lies in the southern basins. Urbanization and sprawl has spread development onto the washes and sediment piedmonts. Runoff from monsoon thunderstorms can quickly overtop a wash, thereby flooding adjacent areas (FEMA, January 1991; DEMA, March 1998).

Generally, southern Arizona is more susceptible to the hazards of heavy rains than are northern and eastern Arizona due to differences in topography, vegetation, and urbanization. However, heavy rainfall occurrences accompanying tropical storms and other severe storms can quickly inundate areas statewide, causing flooding. Frequently, low-intensity; long-duration rains that cover large areas affect Arizona, particularly in the winter. When combined with snowmelt, heavy winter rains cause extensive flooding and erosion (National Weather Service – Phoenix, May 11, 2003).

The highest rainfall amounts during the monsoon season occur in the mountains and in the southeast, often causing flash flooding. The driest areas in the monsoon are along the Colorado River valley in the far west. One of the wettest locations in Arizona during July, August, and September is Greer in the White Mountains where rainfall averages 11.46 inches. By contrast, one of the driest areas during the monsoon months is Yuma, in the far southwest, where the average is only 1.21 (National Weather Service – Phoenix, July 19, 2003).

Temperatures in the Western U.S. rose 2-5°F during the 20th century. This increase was accompanied by precipitation increases of up to 50 percent in some areas of the West, although some places (including Arizona) become drier and experienced more droughts. The two major climate change models, the Canadian Model and the Hadley Model, both forecast continued temperature increases in the West of 5-11°F during the 21st century, including Arizona. Both models also forecast significant increases in rainfall in much of the West, with the increase on the order of 75-100 percent across much of Arizona. These increases may lead to amplified water supplies, although current reservoir systems may be inadequate to control earlier spring runoff and to maintain supplies for the summer (National Assessment Synthesis Team, May 2001). Simply stated, such increases in precipitation could lead to increased flooding in Arizona and elsewhere in the West.

7.3.6.4 Warning Time

Unfortunately, there is no universal answer for every rainfall event. Flood warning times vary based on storm location, direction, intensity, duration, and the topography and size of the drainage area. Depending upon the type of flooding event and the location, the warning time available for a flood can vary from seconds to days. A flash flood or dam break, for example, can cause flooding within minutes, while a tropical storm may precede flooding by days.

Before severe weather watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. However, forecasters cannot issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far in advance. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona originate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

A flood watch is issued by the National Weather Service (NWS) to inform the public and cooperating agencies that current and developing weather is such that there is a threat of rapid flooding (e.g., flash flooding). The occurrence of flooding is, however, neither certain nor imminent. Persons in the watch area are advised to check flood action plans, keep informed, and be ready to take necessary actions if a warning is issued or flooding is observed. A flood watch may also be issued for a dam break. Flood watches are issued as needed to inform the public of conditions that may cause flooding in the next one to two days. A flood watch indicates that there is threat of flooding, but the occurrence is neither certain nor imminent. Flood watches may cover large geographic areas and will be updated with flood statements.

A flood watch is issued if the following conditions occur during the first 48 hours of the forecast period:

- Meteorological, soil, and/or hydrologic conditions indicate a flood is possible but not certain;
- The geographical area covered by a pre-existing flood watch increases or decreases; or
- A dam or levee may fail threatening lives or property, but the threat is not deemed imminent.

The flood watch notification will contain:

- The counties or geographical area covered by the watch (this should be described in terms of well-known river basins, counties, or portions of states);
- The effective time of the watch expressed in terms of hours or in general terms, such as this evening;
- The extent of the hazardous condition expected, i.e., localized or widespread;
- The severity of the hazardous condition expected when this can be done with sufficient degree of confidence; and
- Call to action statements.

A flood warning is a statement issued by the NWS that flash flooding has occurred or is imminent. A flood warning is issued as needed when flooding is expected to threaten life and property after 6 hours after the onset of heavy rain, ice jams, reservoir releases or excessive snow melt. Flood warnings may be in effect for days or even weeks depending on weather and soil conditions, land topography, and the size of the river basin. Updated information will be issued in flood statements. Flood warnings will be re-issued if the river forecast changes significantly.

In Maricopa County, where roughly 60 percent of the State's population resides, warning times for floods depend on the size of the wash, stream, or river. The times can vary from minutes for small washes to days for the larger streams and rivers, and are issued by the NWS in coordination with the United States Army Corps of Engineers (USACE), Bureau of Reclamation (BOR), and other applicable agencies, as well as the Salt River Project, which manages many of the dams, canals, and levees that affect Maricopa County.

The Maricopa County Flood Control District operates a flood threat recognition system called ALERT (Automated Local Evaluation in Real Time). This data is collected by rain and stream gauges. Currently, the system has nearly 232 stream and rain gauges throughout Maricopa County and in neighboring areas. The gauge data is sent by radio waves back to the base station at the District. District staff is able to relay the gauge readings to the NWS, the County Department of Emergency Management, and local dam operators. These agencies use this information to issue the appropriate warnings and, if necessary, prepare for evacuations.

The Maricopa County Department of Emergency Management (MCDEM) maintains emergency call lists of properties in certain locations that have experienced repeated flooding in the past. Residents on these call lists are notified when streamflow or rainfall gauges upstream of their location indicate that flooding is imminent.

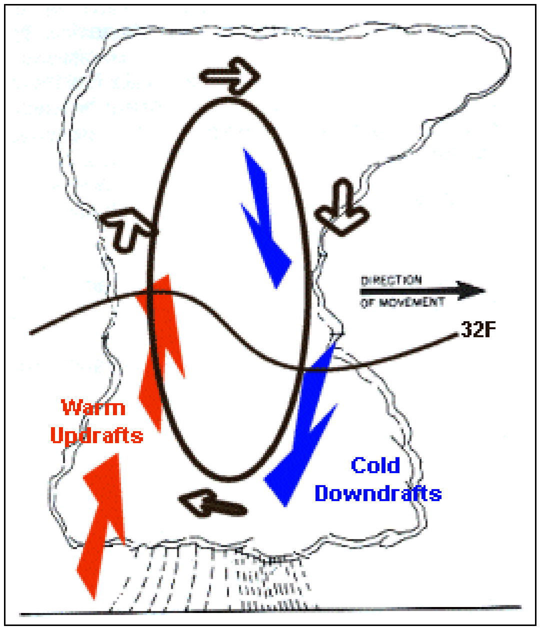
The Flood Control District of Maricopa County is just one of several flood control districts in Arizona. These entities all make significant contributions toward increasing the predictability of floods and improving warning times. In addition, the Arizona Department of Water Resources (ADWR) also manages a statewide network of alert systems that compliment those already discussed.

7.3.7 Hail

7.3.7.1 Nature

Hail is an outgrowth of severe thunderstorms and develops within a low-pressure front as warm air rises rapidly in to the upper atmosphere and is subsequently cooled, as shown in Figure 7-13, leading to the formation of ice crystals. These are bounced about by high velocity updraft winds and accumulate into frozen droplets, falling as precipitation after developing enough weight (FEMA, 1997).

Figure 7-13: How Hail Is Formed



Source: NWS, January 10, 2003

The National Weather Service (NWS) defines severe thunderstorms as those with downdraft winds in excess of 58 miles an hour and/or hail 3/4 inches in diameter or greater. While only about 10 percent of thunderstorms are classified as severe, all thunderstorms are dangerous because they produce numerous dangerous conditions, including one or more of the following: hail, strong winds, lightning, tornadoes, and flash flooding (National Weather Service – Flagstaff).

The size of hailstones varies and is a direct consequence of the severity and size of the thunderstorm. The higher the temperatures at the Earth's surface, the greater the strength of the updrafts, and the greater the amount of time the hailstones are suspended, the larger the size of the hailstones. Hailstones vary widely in size, as shown in Table 7-15. Note that hail penny size (3/4 inches in diameter) or larger is considered severe.

Table 7-15: Estimating Hail Size	
Size	**Inches in Diameter**
Pea	1/4 inch
Marble/mothball	1/2 inch
Dime/Penny	3/4 inch
Nickel	7/8 inch
Quarter	1 inch
Ping-Pong Ball	1 1/2 inch
Golf Ball	1 3/4 inches
Tennis Ball	2 1/2 inches
Baseball	2 3/4 inches
Tea cup	3 inches
Grapefruit	4 inches
Softball	4 1/2 inches
Source: NWS, January 10, 2003.	

Hailstorms occur most frequently during the late spring and early summer, when the jet stream moves northward across the Great Plains. During this period, extreme temperature changes occur from the surface up to the jet stream, resulting in the strong updrafts required for hail formation.

7.3.7.2 History

Hail causes $1 billion in damage to crops and property each year. The costliest hailstorm in the United States was in Denver in July 1990 with reported damage of $625 million. The largest hailstone ever recorded, which fell in Coffeyville, Kansas on September 3, 1970, measured over 5.6 inches in diameter and weighed more almost 2 pounds (NWS, January 10, 2003).

A total of 13 hail significant hail events in Arizona were identified, as shown in as shown in Table 7-3. These events caused at least one injury, one death, $50,000 worth of damage, or were severe enough to be identified in historical records. None of these events prompted a disaster declaration, although six injuries were recorded and over $18.8 million in damage, most of which was caused by one event (see below). These events include the following:

- On March 12, 1958, 4-inch diameter hail was recorded in Parker (NCDC, Storm Event Database, January 2003).
- Tropical moisture on September 24 and 25, 1976 caused heavy thunderstorms with intermittent hail to the Tucson area that rapidly filled the normally dry washes, especially the Pantano Wash and Rillito Creek. Flooding occurred on almost 100 streets and roads throughout the city, particularly on the north and east side, where local amounts of rain ranged to 3.5 inches. Nearly a dozen cars, some with occupants, where swept into washes on the east side. Sizes of hail ranged upward to ¾ inches in diameter, with some as big as golf balls, and up to 5 inches of hail covered the ground in the Mt. Lemmon (NWS, March 29, 2002).
- The most damaging hailstorm on record in Arizona occurred on September 15, 1999, approximately 10 miles northeast of Prescott. The storm caused two injuries and $18.0 million worth of damages (NCDC, Storm Event Database, January 2003).
- September 19, 1999, hail and strong winds ripped through the Coolidge area and damaged thousands of acres of cotton just weeks before it would have been harvested. Trees were uprooted in Coolidge, and power poles were down in Coolidge and Florence. Heavy rain was also recorded at the Casa Grande Ruins National Monument where 2.02 inches fell in about 45 minutes. About 41 homes in

Blackwater, on the Gila River Indian Community, had either roof damage, broken windows, or door and skirting damages. There was an estimated $100,000 property damage and $50,000 crop damage (NCDC, Storm Event Database, January 2003).

- On October 7, 2002, there were numerous reports of large hail throughout the West Valley, including Sun City, Peoria, and Phoenix. Winds reached over 60 mph, damaged homes, blew down power poles, and uprooted trees. Streets were also flooded in the West Valley as rain totals were as much as 1.85 inches. Arizona Public Service and Salt River Project estimated over 11,000 customers were without power. The storm caused an estimated $200,000 property damage (NCDC, Storm Event Database, January 2003).

According to a 1994-1995 study conducted by the Performance Based Studies Research Group, Arizona ranked 37th among the states in the number of severe and oversized hailstone events, as shown in Table 7-16. During the study period, five severe hailstorms occurred in Arizona, all in the month of September, causing over $100,000 damage in Pima and Yavapai Counties.

Table 7-16: Overall Oversize Hail Damage Statistics For Arizona (1994-1995)

Description	Results
National rating in number of oversize hailstorms	37
Total number of oversize and severe hail occurrences	5
Overall percentage of oversize hail	40 %
Maximum size of oversize hail (inches)	4.5
Average size of hail (inches)	2.5
Minimum size of hail (inches)	1.75
Property loss due to oversize hail	0.1 M
Property loss due to severe hail	-

Source: Kashiwagi, 1998.

Table 7-17 displays the number of hailstorms by hailstone size for Arizona counties between 1950 and 2001. Based on past occurrences, Arizona is far more likely to receive hailstorms with hailstones less than 2 inches in diameter. Compared to other counties, Maricopa, Yavapai, Pima, and Coconino have received the greatest number of hailstorms.

Table 7-17: Hailstone Occurrence by Size and County in Arizona, 1950 to 2001

	Inches in Diameter								
County	**< 1**	**1 to 1.5**	**1.5 to 2**	**2 to 2.5**	**2.5 to 3**	**3 to 3.5**	**3.5 to 4**	**4 to 4.5**	**Total**
Apache	1								1
Cochise	15	9	9	1					34
Coconino	24	18	8	1					51
Gila	9	4	6		2	1			22
Graham	3		1	1				1	6
Greenlee	1		1						2
La Paz	1	1	2						4
Maricopa	33	23	12		1				69
Mohave	6	7	10						23
Navajo	7	4	1	2					14
Pima	28	20	11		1				60
Pinal	17	7	1						25
Santa Cruz	3		2	1					6
Yavapai	28	22	9	2	1			1	63
Yuma	6	3	1						10
Total	**182**	**118**	**74**	**8**	**5**	**1**		**1**	**390**

Source: SeverePlot Software, v.2.0, Storm Prediction Center, NOAA.

7.3.7.3 Probability and Magnitude

Table 7-17 depicts the annual frequency of hailstorms in Arizona, with much of northern Arizona expected to have four to five annually days with hailstorms. Note, however, that the map originally dates from 1991, with no more recent frequency map available. As noted above, most hail in Arizona is less than 2 inches in diameter. Severe thunderstorms can occur in any month of the year, but the months of July, August and September account for most of the severe thunderstorm occurrences in Arizona (National Weather Service – Flagstaff).

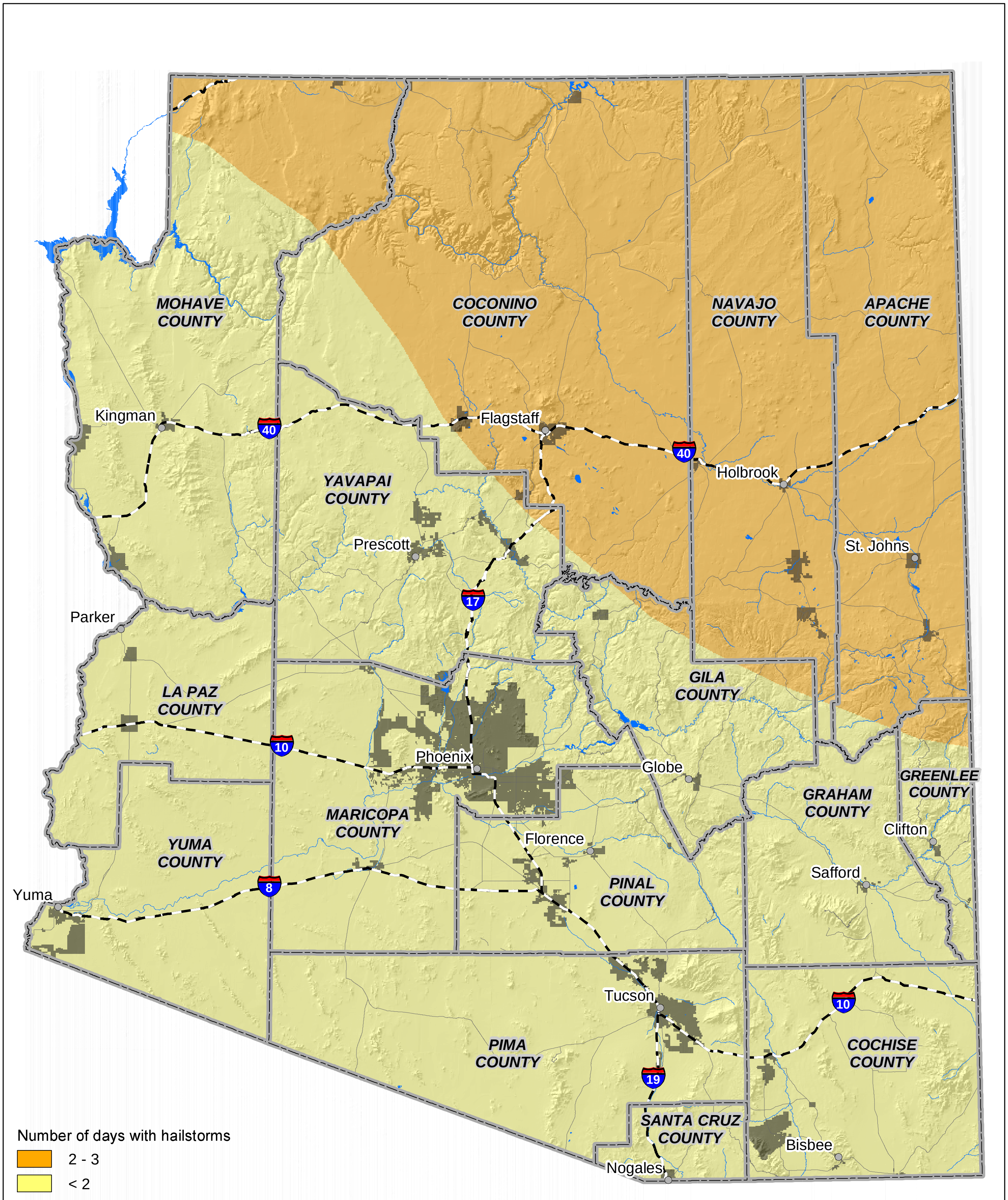
The areal extent and severity of hailstorms is somewhat similar to that for maximum thunderstorm and tornado activity. Severe thunderstorms are likely to generate concurrent effects, such as severe winds, tornadoes, and hail.

7.3.7.4 Warning Time

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

Hail is a consequence of severe thunderstorms. The NWS issues a severe thunderstorm watch when conditions are favorable for the development of severe thunderstorms. The local NWS office considers a thunderstorm severe if it produces hail at least 3/4-inch in diameter, wind of 58 mph or higher. When a watch is issued for a region, residents are encouraged to continue normal activities but should remain alert for signs of approaching storms, and continue to listen for weather forecasts and statements from the local NWS office. When a severe thunderstorm has been detected by weather radar or one has been reported by trained storm spotters, the local NWS office will issue a severe thunderstorm warning. A severe thunderstorm warning is an urgent message to the affected counties that a severe thunderstorm is imminent. The warning time provided by a severe thunderstorm watch may be on the order of hours, while a severe thunderstorm warning typically provides warning time in the range of an hour or less.

Unfortunately, there is no universal answer for every storm event. Warning times vary based on storm location, direction, intensity, duration, and the topography and size of the drainage area. Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. However, forecasters cannot issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far ahead. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona originate from NWS (NWS) offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.



Note: Annual frequency of hailstorms in Arizona

Source: HAZUS99; ALRIS July 2001; FEMA 1997; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

N

0 25 50
Miles

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-14

Annual Frequency of Hailstorms in Arizona

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7.3.8 Hazardous Material (HAZMAT) Event

7.3.8.1 Nature

Hazardous materials (HAZMAT) includes hundreds of substances that pose a significant risk to humans. These substances may be highly toxic, reactive, corrosive, flammable, radioactive or infectious. They are present in nearly every community in the U.S., where they may be manufactured, used, stored, transported, or disposed. Because of their nearly ubiquitous presence, there are hundreds of HAZMAT release events annually in the U.S. that contaminate air, soil, and groundwater resources, potentially triggering millions of dollars in clean-up costs, human and wildlife injuries, and occasionally cause human deaths (FEMA, 1997).

Hazardous material releases may occur from any of the following:

- Fixed site facilities (e.g., refineries, chemical plants, storage facilities, manufacturing, warehouses, wastewater treatment plants, swimming pools, dry cleaners, automotive sales/repair, gas stations);
- Highway and rail transportation (e.g., tanker trucks, chemical trucks, railroad tankers);
- Marine transportation (e.g., bulk liquefied gas carriers, oil tankers, tank barges);
- Air transportation (e.g., cargo packages); and
- Pipeline transportation (liquid petroleum, natural gas, other chemicals).

In response to concerns over the environmental and safety hazards posed by the storage and handling of toxic chemicals in the U.S., Congress passed Emergency Planning and Community Right to Know Act (EPCRA). These concerns were triggered by the 1984 disaster in Bhopal, India, in which more than 2,000 people died or were seriously injured from the accidental release of methyl isocyanate from an American owned Union Carbide plant. To reduce the likelihood of such a disaster in the U.S., EPCRA established specific requirements on federal, state and local governments, Indian tribes, and industry to plan for hazardous materials emergencies.

EPCRA's Community Right-to-Know provisions help increase the public's knowledge and access to information on chemicals at individual facilities, their uses, and releases into the environment. States and communities working with facilities can use the information to improve chemical safety and protect public health and the environment (EPA, May 2003). Under EPCRA, hazardous materials must be reported to the Environmental Protection Agency (EPA), even if they do not result in human exposure. Such releases may include the following:

- Air emissions (e.g., pressure relief valves, smokestacks, broken pipes, water or ground emissions with vapors);
- Discharges into bodies of water (e.g., outflows to sewers, spills on land, water runoff, contaminated groundwater);
- Discharges onto land;
- Solid waste disposals in onsite landfills;
- Transfer of wastewater to public sewage plants; and
- Transfers of waste to offsite facilities for treatment or storage.

In addition to accidental human-caused hazardous material events, such as an unintended release from a pressure valve or a transportation accident, natural hazards may cause the release of hazardous materials and complicate response activities. The impact of earthquakes on fixed facilities may be particularly bad due to the impairment of the physical integrity or even failure of containment facilities. The threat of any hazardous material event may be magnified due to restricted access, reduced fire suppression and spill containment, and even complete cut-off of response personnel and equipment. In addition, the risk of terrorism involving hazardous materials is considered a major threat due to the location of hazardous material facilities and transport routes throughout communities and the oftentimes limited anti-terrorism security at these facilities.

Due to the high level of risk posed by hazardous materials, numerous federal, state and local agencies are involved in their regulation, including the U.S. Environmental Protection Agency (EPA), U.S. Department of Transportation (DOT), National Fire Protection Association (NFPA), Federal Emergency Management Agency (FEMA), U.S. Army, and the International Maritime Organization.

Unless exempted, facilities that use, manufacture, or store hazardous materials in the U.S. fall under the regulatory requirements of EPCRA, enacted as Title III of the federal Superfund Amendments and Reauthorization Act ((SARA) 42 U.S.C. §§11001-11050 (1988)), and under Arizona Revised Statutes §26-350. EPCRA has four major provisions:

- Emergency Planning (Section 301-303) is designed to help communities prepare for and respond to emergencies involving hazardous substances. It requires every community in the United States to be part of a comprehensive emergency response plan.
- Emergency Release Notification (Section 304) includes a list of chemicals that if spilled must be reported, including Extremely Hazardous Substances (EHS). The SERC supervises and coordinates activities of the LEPCs, establishes procedures for receiving and processing public requests for information collected under EPCRA, and reviews LEPC developed local emergency response plans. Facilities holding an Extremely Hazardous Substance (EHS) at quantities exceeding the Threshold Planning Quantities (TPQ) must notify the SERC and LEPC and provide a representative to participate in the county emergency planning process. The Governor of Arizona has designated a State Emergency Response Commission (SERC) responsible for implementing EPCRA provisions within Arizona. The SERC oversees fifteen countywide Local Emergency Planning Committees (LEPC) districts (Maricopa County Department of Emergency Management, May 2003).
- Hazardous chemical storage reporting requirements (Sections 311-312) that requires facilities possessing a threshold reporting quantity of a hazardous material under EPCRA (Section 311/312, 40 CFR Part 370) to submit an annual chemical inventory report (Tier II Hazardous Chemical Inventory Form) to the SERC, LEPC and local fire department by March 1 of each year; and
- Toxic chemical release inventory (Section 313).

Of the hundreds of hazardous materials, under the EPCRA regulatory scheme, those hazardous materials that pose the greatest risk for causing catastrophic emergencies are identified as Extremely Hazardous Substances (EHSs). As noted above, the presence of EHSs in quantities at or above Threshold Planning Quantities (TPQ) require additional emergency planning and mitigation activities. These chemicals are identified by the US EPA in the *List of Lists – Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112 of the Clean Air Act* (EPA, October 2001).

Releases of EHSs occur during transport and from fixed facilities, with transported EHSs exposed to greater risk of release due to the inherently greater risk of transport. Transportation related releases are generally more troublesome because they may occur anywhere, including close to human populations, critical facilities, or sensitive environmental areas. Transportation related EHS releases are also more difficult to mitigate due to the variability of locations and distance from response resources.

It should be noted that while comprehensive and readily accessible information is available on hazardous material release and facilities subject to EPCRA, there are numerous other sources of information on hazardous material facilities and incidents that are beyond the scope of this plan. According to the Arizona Department of Environmental Quality (ADEQ),a complete analysis of potential hazardous material events would include all of the following:

- Risk Management Plan (RMP) facilities;
- Tier II Hazardous Chemical Inventory Form facilities;
- Toxic Release Inventory (TRI) facilities;
- Pipelines and related facilities;

- Railroad transportation facilities;
- Explosive storage, sales, use, and manufacturing facilities;
- Hazardous Materials Management Plan (HMMP) permit and Hazardous Materials Inventory Statement (HMIS) facilities;
- Hazardous waste facilities (RCRA information and RMS databases);
- Arizona Department of Environmental Quality (ADEQ) Material Incident Logbook;
- National Response Center Incident Database;
- U.S. Department of Transportation (DOT) Incident Database;
- Arizona Department of Transportation (ADOT);
- Trucking terminal facilities;
- U.S. Office of Occupational Safety and Health Administration (OSHA) Injury, Illness, and Fatality Database;
- 911 regional dispatch centers (e.g., Phoenix);
- Environmental Protection Agency (EPA) Envirofacts and Window to My Environment;
- EPA Enforcement and Compliance History Online (ECHO); and
- EPA Central Data Exchange. (ADEQ, April 3, 2003)

7.3.8.2 History

Some of the worst hazardous material events have occurred outside of the U.S., such the 1984 incident in Bhophal, India, which killed or seriously injured more than 2,000 people. The following is a summary of hazardous material events by type in the U.S.:

- The National Response Center (NRC) reported an average of 280 hazardous material releases and spills occurred at fixed sites annually during the period 1987-1990.
- The US Department of Transportation reported an average of 6,774 hazardous material events annually during the period 1982-1991, with highways accounting for 81.4 percent, railroads 14.7 percent, and other events 6.6 percent.
- Highway transportation hazardous material events have caused more than 100 deaths, 2,800 injuries, and $22.4 million in damages (FEMA, 1997).

Hazardous material (HAZMAT) releases are a major concern in Arizona. The Arizona Division of Emergency Management (ADEM) provided information on the declared hazardous material events, while information on nearly all of the undeclared events came from the National Response Center (NRC). In addition, hazardous material release reports were gathered from the NRC for the period 1990-2002 and screened to include only releases reported to the NRC of Extremely Hazardous Substances (EHSs) that met the Reportable Quantity (RQ) test under Section 304 of EPCRA (see *EPA List of Lists,* Section 304 EHS RQ). These materials pose the greatest risk for causing catastrophic emergencies.

A total of 81 significant hazardous material (HAZMAT) events in Arizona were identified, eight of which prompted a disaster declaration by the Governor, as shown in as shown in Table 7-3. For all 81 incidents, one death, 24 injuries, and $100.0 million in damages were recorded (although the damages figure is from a single event with no damage information reported for all other events). Of the 73 undeclared hazardous materials incidents, the NRC accounted for 71 (all of which were Extremely Hazardous Substance incidents). These events include the following:

- On February 28, 1994, an Air National Guard F-16 jet crashed near Duncan, killing the pilot and released hydrazine.

- One person was injured when a chlorine release during the filling of a one-ton cylinder in Glendale on September 18, 1995.
- On May 21, 1999, a chlorine release at the Arizona State Prison in Fort Grant injured one person.
- Twelve people were injured by a chlorine leak on September 25, 1999 in Nogales.
- Three people were injured by a chlorine release in Phoenix on May 15, 2000.
- A major fire at a warehouse in Phoenix on August 2, 2000, resulted in five injuries due to chlorine and an estimated $100 million in damages. The fire, which wasn't extinguished until the next day, required four alarms and numerous special apparatus. Over 80 civilians had to be evacuated from the surrounding neighborhood and several fire fighters and police officers were treated for smoke inhalation. The fire completely destroyed the 85,000 sq. ft. warehouse. A portion of the building was a home and garden supply business which stored oxidizers (e.g., chlorine), fertilizers, and pesticides (National Fire Protection Association, 2000).
- On July 17, 2001, the release of chlorine at the Pima County Waste Water Plant injured one person.

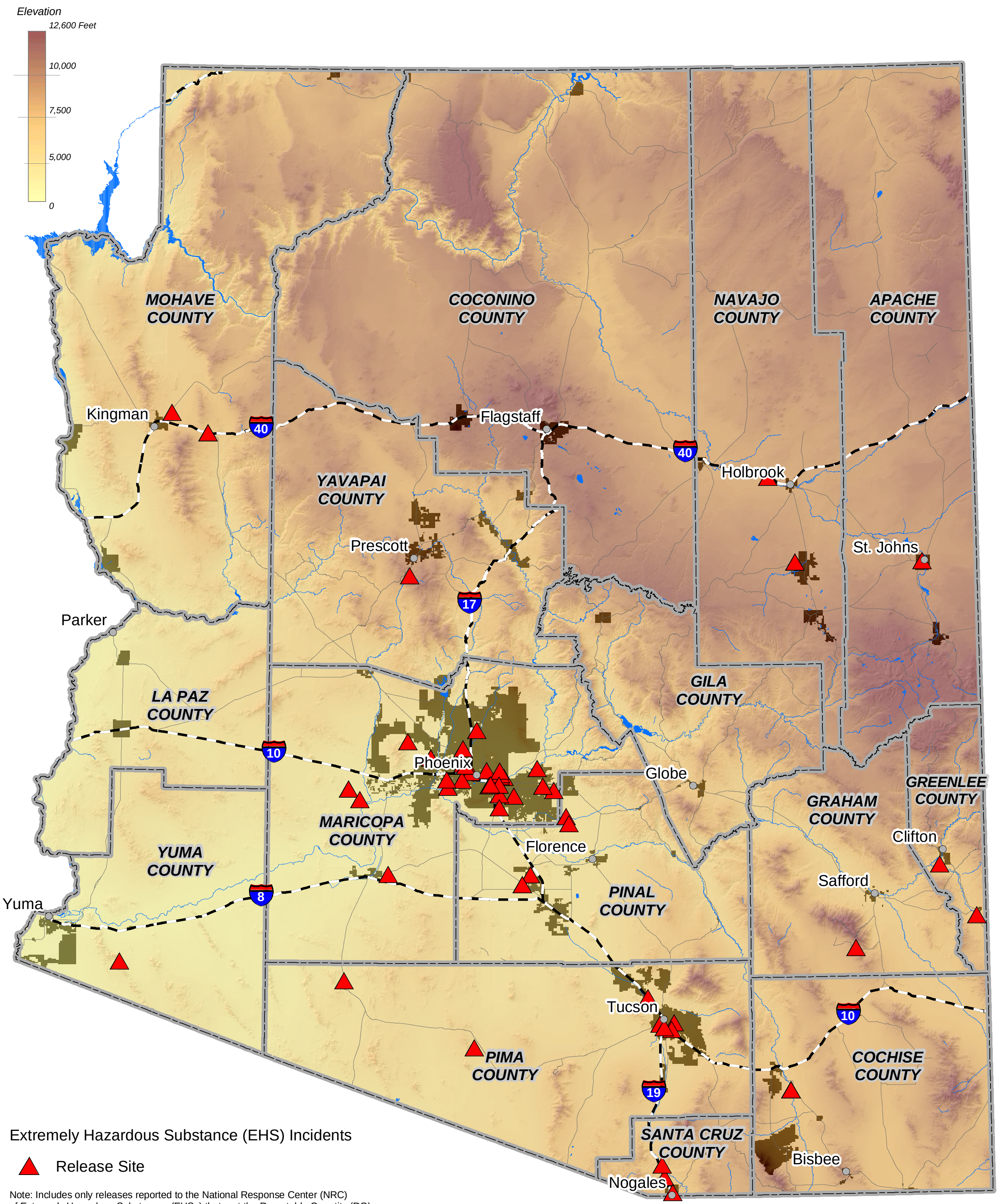
Maricopa County had 33 or nearly half of the 71 Extremely Hazardous Substance (EHS) incidents reported to the NRC during the period 1990-2000, as shown in Table 7-18. This is not surprising given the overall level of development in Maricopa County, particularly the concentration of industry and major infrastructure there. Somewhat surprising is the fact that Cochise County had the second highest number of incidents (10), which may be explained by location of a major transportation route (Interstate 10) there. Pima County, another highly developed area, had the third highest number of incidents. The location of these incidents is shown in Figure 7-15. Note the concentration in the urbanized areas and along transportation corridors.

Table 7-18: National Response Center (NRC) Extremely Hazardous Substances (EHSs) Incidents in Arizona, 1990-2002

County	Incidents	Percent
Apache	1	1.4%
Cochise	10	14.1%
Coconino	-	0.0%
Gila	-	0.0%
Graham	1	1.4%
Greenlee	2	2.8%
La Paz	-	0.0%
Maricopa	33	46.5%
Mohave	3	4.2%
Navajo	3	4.2%
Pima	7	9.9%
Pinal	5	7.0%
Santa Cruz	3	4.2%
Yavapai	1	1.4%
Yuma	2	2.8%
Total	**71**	**100.0%**

Note: Includes only releases reported to the National Response Center (NRC) of Extremely Hazardous Substances (EHSs) that met the Reportable Quantity (RQ) test under Section 304 of EPCRA (see *EPA List of Lists*, Section 304 EHS RQ).

Source: NRC, May 2003; URS, October 2003.



Extremely Hazardous Substance (EHS) Incidents

Release Site

Note: Includes only releases reported to the National Response Center (NRC) of Extremely Hazardous Substances (EHSs) that met the Reportable Quantity (RQ) test under Section 304 of EPCRA (see EPA Lists of Lists, Section 304 EHS RQ).

Source: HAZUS99; ALRIS July 2001; NRC May 2003; EPA October 2001; URS October 2003

LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Miles

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Figure 7-15

State of Arizona Enhanced Hazard Mitigation Plan

Extremely Hazardous Substances (EHS) Incidents in Arizona, 1990-2002

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7.3.8.3 Probability and Magnitude

Comprehensive information on the probability and magnitude of hazardous material events across all types of sources (e.g., fixed facility, transport vehicle) is not available. Wide variations in the characteristics of hazardous material sources and between the materials themselves make such an evaluation very difficult.

The US Department of Transportation's Hazardous Materials Transportation Program is one of the most advanced probability and magnitude estimation programs. The program collects information on unintentional releases of hazardous materials, including the consequences, and analyzes them. One of the major efforts of the program is to identify low probability, high consequence events (which may not be apparent from incident data) and providing appropriate levels of protection (DOT, September 2003).

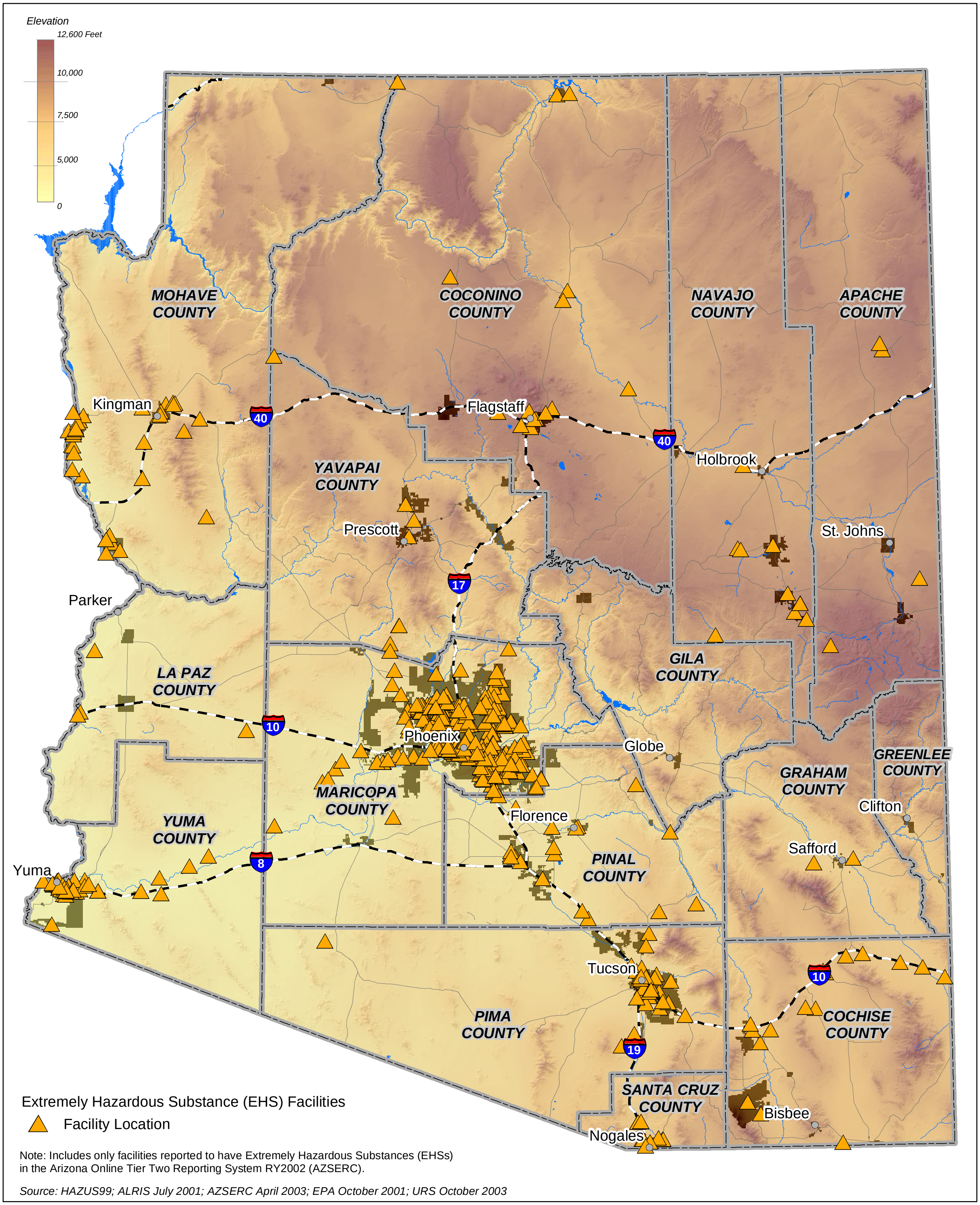
While it is beyond the scope of this plan to evaluate the probability and magnitude of hazardous material events in Arizona in detail, it is possible to determine the exposure of population, buildings, and critical facilities should such an event occur. The starting point for this analysis is the approximately 4,500 facilities in Arizona that were required in 2000 under EPCRA to file a Tier II Material Inventory Report annually because of the presence of hazardous materials. Of these approximately 4,500 facilities in Arizona, 845 facilities were identified as having Extremely Hazardous Substance (EHS), as shown in Table 7-19 and Figure 7-16. As noted above, EHSs pose the greatest risk for causing catastrophic emergencies and, as such, facilities with these are considered a greater threat than most. Major concentrations of EHS facilities are to be found in Maricopa, Yuma, Pima, and Mohave Counties.

Table 7-19: Extremely Hazardous Substance (EHS) Facilities in Arizona, 2002

County	Facilities	Percent
Apache	4	0.5%
Cochise	20	2.4%
Coconino	19	2.2%
Gila	5	0.6%
Graham	2	0.2%
Greenlee	1	0.1%
La Paz	8	0.9%
Maricopa	508	60.1%
Mohave	42	5.0%
Navajo	11	1.3%
Pima	67	7.9%
Pinal	35	4.1%
Santa Cruz	12	1.4%
Yavapai	4	0.5%
Yuma	107	12.7%
Total	**845**	**100.0%**

Note: Includes only facilities with Extremely Hazardous Substances (EHSs). Based on Arizona Online Tier Two Reporting System RY2002.

Source: Arizona Emergency Response Commission, April 6, 2003.



LEGEND

Interstate — Highway

City — Major Stream

County — Lake

County Seat

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State of Arizona
Enhanced Hazard
Mitigation Plan

Figure 7-16
Extremely Hazardous Substance (EHS) Facilities in Arizona, 2002

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ARIZONA EMERGENCY MANAGEMENT

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7.3.8.4 Warning Time

The amount of warning time for a hazardous material (HAZMAT) event varies widely by type and size of event. The release of a small amount of non-gaseous hazardous material onto land that is immediately contained may allow significant warning time to nearby people (perhaps hours, not to mention the fact that such an event presents a relatively low level of immediate risk). By contrast, the release of a large amount of a gaseous Extremely Hazardous Substance (EHS) may provide no warning time (potentially seriously injuring or killing those nearby and effectively delaying the detection of and response to such an event).

7.3.9 Landslide

7.3.9.1 Nature

Landslides are the downward and outward movement of slopes and refer to a number of types of events, including mudflows, mudslides, debris flows, rock falls, rock slides, debris avalanches, debris slides, and earth flows. Landslides may be any combination of natural rock, soil, or artificial fill. Landslides are classified by the type of movement and the type of material. The types of movement are slides, flows, lateral spreads, and falls and topples. The types of material are predominately coarse soils, predominantly fine soils, or bedrock (FEMA, 1997).

Below is a brief discussion of the various types of landslide movements. A combination of two or more landslide movements is referred to as a complex movement.

- Slides are downward displacement along one or more failure surfaces of soil or rock. The material may be a single, intact mass or a number of pieces. The sliding may be rotational (turning about a point) or translational (movement roughly parallel to the failure surface).
- Flows are distinguished from slides by high water content and velocities that resemble those of viscous liquids. Flows are a form of rapid mass movement by loose soils, rocks and organic matter, together with air and water, that form a slurry flowing rapidly downhill.
- Lateral spreads are large movements of rock, fine-grained soils (e.g., quick clays), or granular soils, distributed laterally. Liquefaction may occur in loss, granular soils, which may occur spontaneously due to changes in pore-water pressure or due to earthquake vibrations.
- Falls and topples are masses of rocks or material that detach from a steep slope or cliff that free fall, roll, or bounce, with movements typically rapid to extremely rapid. Earthquakes commonly trigger rock falls.

Almost any steep or rugged terrain is susceptible to landslides under the right conditions. The most hazardous areas are canyon bottoms, stream channels, areas near the outlets of canyons, and slopes excavated for buildings and roads. Slide potentials are enhanced where slopes are destabilized by construction or river erosion. Road cuts and other altered or excavated area of slopes are particularly susceptible to landslides and debris flows. Rainfall and seismic shaking by earthquakes or blasting can trigger them.

Debris flows (also referred to as mudslides) generally occur during intense rainfall on water saturated soil. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to speeds as great as 35 miles per hour. Multiple debris flows that start high in canyons commonly funnel into channels. Beginning in swales on steep slopes, they merge, gain volume, and travel long distances from their source, making areas down slope from swales particularly hazardous. Surface runoff channels, such as along roadways and below culverts, are common sites of debris flows and other landslides (USGS, 2000).

Landslides often occur together with other major natural disasters, such as the following, thereby exacerbating relief and reconstruction efforts:

- Floods and landslides are closely related and both involve precipitation, runoff, and ground saturation, which may be the result of severe thunderstorms or tropical storms.
- Volcanoes often cause massive landslides due to earthquake, upheaval, collapse, explosion, or sudden snowmelt.
- Earthquakes may cause landslides ranging from rock falls and topples, to massive slides and flows.
- Landslides into a reservoir may indirectly compromise dam safety or a landslide may even affect the dam itself.
- Wildfires may remove vegetation from hillsides, significantly increasing runoff and landslide potential.

7.3.9.2 History

Landslides are a major geologic hazard because they are widespread, occurring in all 50 states. On average, landslides cause $1-2 billion in damages annually and more than 25 fatalities. Landslides pose serious threats to highways and structures that support fisheries, tourism, timber harvesting, mining, and energy production as well as general transportation Expanding urban development and other land uses have increased the incidence of landslide disasters in the U.S. (USGS, June 7, 2002). Examples of major landslides in the U.S. include the following:

- The catastrophic 1980 eruption of Mount St. Helens in Washington was preceded by the by the development of a large landslide on the north side of the volcano.
- Rains accompanying the El Nino effect triggered numerous landslides across Southern California in 1983-84 and 1998.
- The Northridge earthquake in 1994 in the San Fernando Valley triggered thousands of landslides in the Santa Susanna Mountains north of the epicenter.
- A massive landslide occurred on April 22, 1998, near Aromas, California, 15 miles north of Salinas,. The slide severed two Pacific Gas And Electric (PG&E) natural-gas pipelines, cutting off gas service to 60,000 customers in Santa Cruz County and parts of Monterey County.

Only one significant landslide event in Arizona was identified, as shown in as shown Table 7-3, with no fatalities, injuries, or damages sustained. The event was a massive landslide that blocked the Moenkopi Wash near Tuba City in Coconino County, in December 1995. Due to the landslide creating an unstable damming of waters and the threat of an imminent flash flood impacting downstream communities, a Gubernatorial emergency was declared (ADEM, March 6, 2003; Arizona National Guard, 1997).

The only other notable specific landslides identified were the widespread rock falls, rock slides, and avalanches reported throughout Arizona due to the 1887 earthquake in Sonora, Mexico. Huge blocks of rock are reported to have fallen throughout the state and the southeastern part of the state was severely affected by various forms of catastrophic down slope movement (Jenney and Reynolds, 1989).

In a study titled *Landslide Overview of the Conterminous United States* (1997), the U.S. Geological Survey (USGS) has mapped historic landslide incidence and susceptibility at the national level and made the data available for use for smaller geographic areas, such as Arizona. To prepare the map, individual formations or groups of formations were evaluated and classified as having high, medium, or low landslide incidence (number of landslides). If 15.1 percent or more of an area had been involved in a landslide, it was classified as having a high incidence of landslides. If 1.5-15.0 percent of an area had been involved in a landslide, it was classified as having a medium incidence of landslides. Note that the study authors acknowledge that the incidence categories are largely subjective due to the lack of data for precise determinations. Assigning an area the lowest incidence categories does not mean that landslides have not occurred in that area, just that no information indicating such occurrences was available. Also, due to the highly generalized nature of the map, it is unsuitable for local planning or site selection purposes.

As shown in Figure 7-17, landslides have occurred in a number of areas in Northern Arizona on the Colorado Plateau. A large concentration of high incidence is apparent in the central part of Navajo County, near Polacca. Another major concentration of high incidence is located near Page in northernmost Coconino County. Several other concentrations of high incidence are located in the northwestern corner of the state in Mohave County. A large concentration of medium incidence is located around St. Johns in Apache County.

These concentrations are consistent with other analyses of slope instability in Arizona. Previous analyses have identified the most widespread evidence of landslides in Arizona on the Colorado Plateau, with its many precipitous canyons and steep, or formerly steep, cliffs bounding the numerous mesas and buttes (Jenney and Reynolds, 1989). The USGS classifies the Colorado Plateau as one of the four most landslide prone areas of the country. In southern and central Arizona Basin and Range Province rockslides are also common (Arizona Geological Survey, 2003).

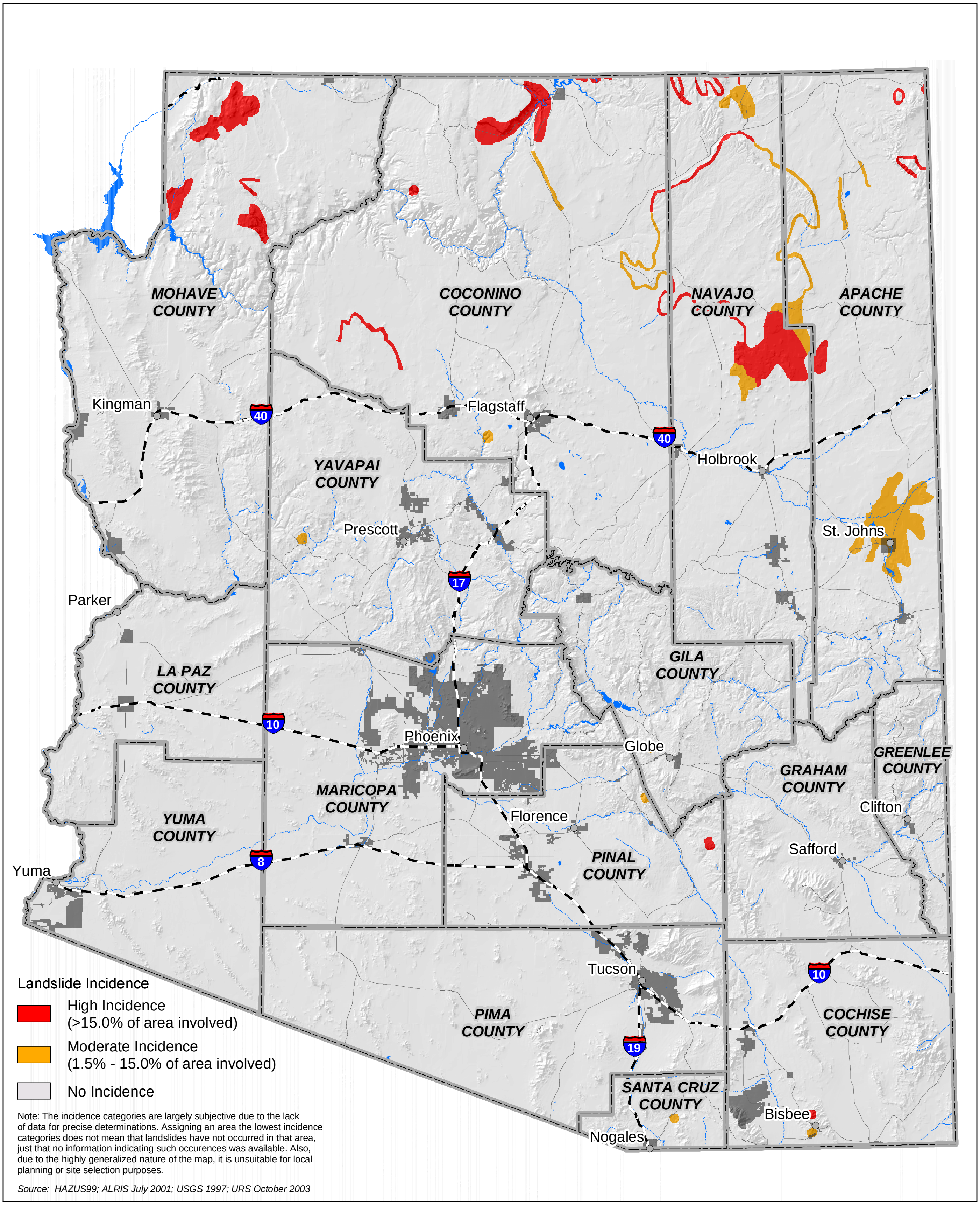
Arizona State University and the University of Texas at El Paso have teamed up to construct an integrated data system focusing on the Transition Zone between the Colorado Plateau and the Basin and Range Province, located primarily in Arizona and New Mexico. Known as the Geoinformatics project, the work is being funded by the National Science Foundation (NSF). A component of the project is the identification and mapping of specific landslides by type in Arizona, as shown in Figure 7-18.

7.3.9.3 Probability and Magnitude

According to the Arizona Geological Survey (AZGS), areas prone to landslides or mass movement are widespread in Arizona. As noted above, almost any steep or rugged terrain is susceptible to slope failure under the right conditions. Debris flows are the most common form of mass wasting in the desert regions of Arizona. Arizona's arid climate results in thin soils and sparse vegetation throughout much of the state. Without extensive plant roots to help hold weathered rocks and soil in place, even small rainfalls can cause debris flows. Due to their high water content, debris flows behave as a slurry and naturally follow drainages. Areas in which soils are deeper, especially those with expansive clay, are susceptible to landslides during heavy rain, due to the weakening of the cohesion of clay. Due to the high clay content of soil and weathered rock outcrops, the Colorado Plateau is classified by the USGS as one of the four most landslide-prone areas in the country. As Arizona's population grows, more development is taking place near mountain fronts and on slopes. The potential for property damage increases as people move into steeper areas more prone to slope failure (February 7, 2003).

A second component of the USGS study titled *Landslide Overview of the Conterminous United States* (1997), is the mapping of landslide susceptibility. To prepare the map, individual formations or groups of formations were evaluated and classified as having high, medium, or low landslide susceptibility. This map builds on the previous landslide incidence map, with the assumption that anomalous precipitation or changes in the existing conditions could initiate movement in rocks and soils that have numerous landslides incidence in parts of their outcrop areas. If 15.1 percent or more of an area may be involved in a landslide, it is classified as having a high susceptibility to landslides. If 1.5-15.0 percent of an area may be involved in a landslide, it is classified as having a medium susceptibility to landslides. Note that the study authors acknowledge that the susceptibility categories are largely subjective due to the lack of data for precise determinations. Assigning an area the lowest susceptibility categories does not mean that landslides may not occur in that area. Also, due to the highly generalized nature of the map, it is unsuitable for local planning or site selection purposes.

As shown in as shown in Figure 7-19, landslides may occur across large portions of Northern Arizona on the Colorado Plateau. Extensive areas in Apache, Navajo, Coconino, and Mohave Counties have a high or medium susceptibility to landslides.



LEGEND

- Interstate
- City
- County
- County Seat
- Highway
- Major Stream
- Lake

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Figure 7-17
Landslide Incidence in Arizona

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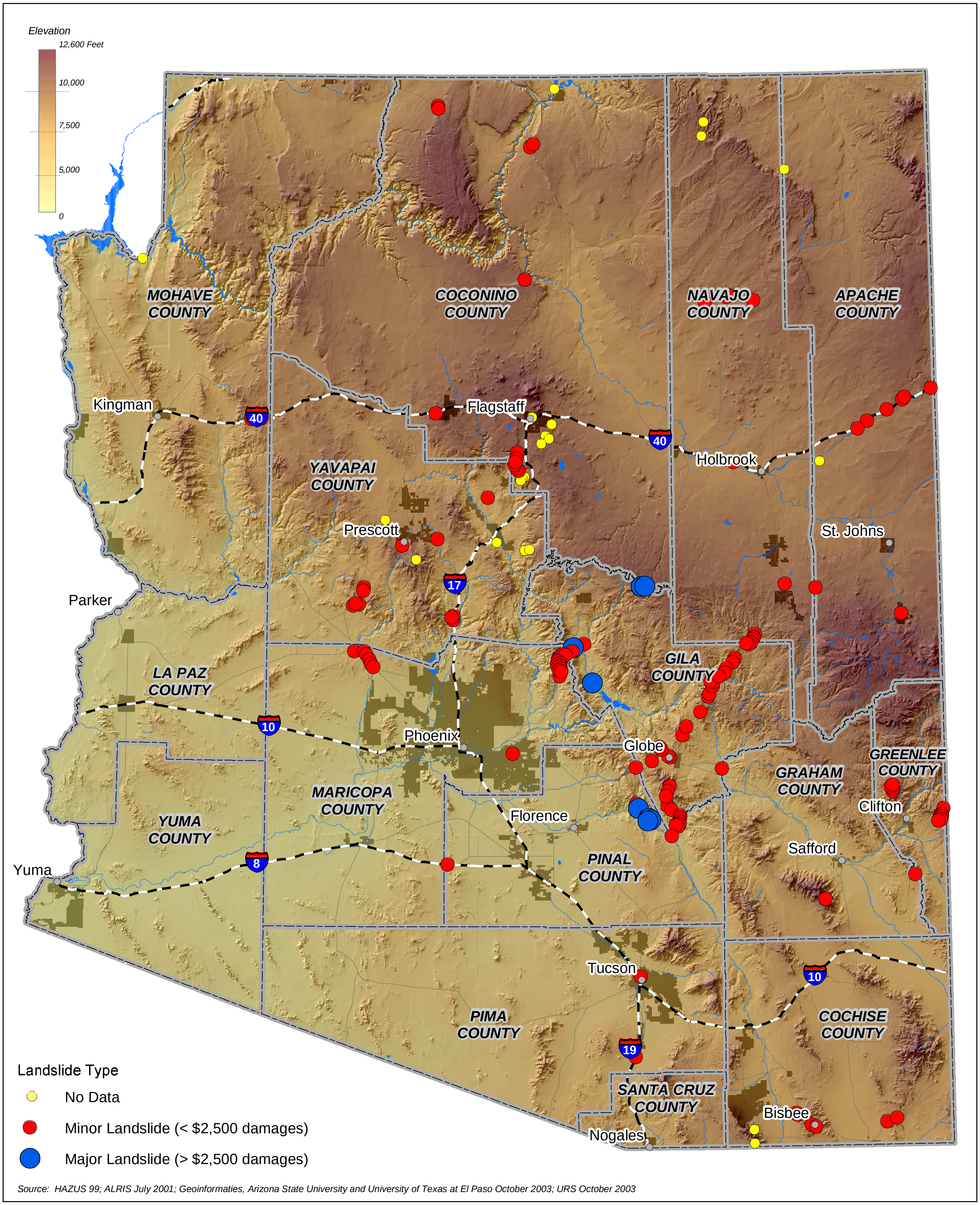

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December 2003

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-18

Landslides by Type in Arizona

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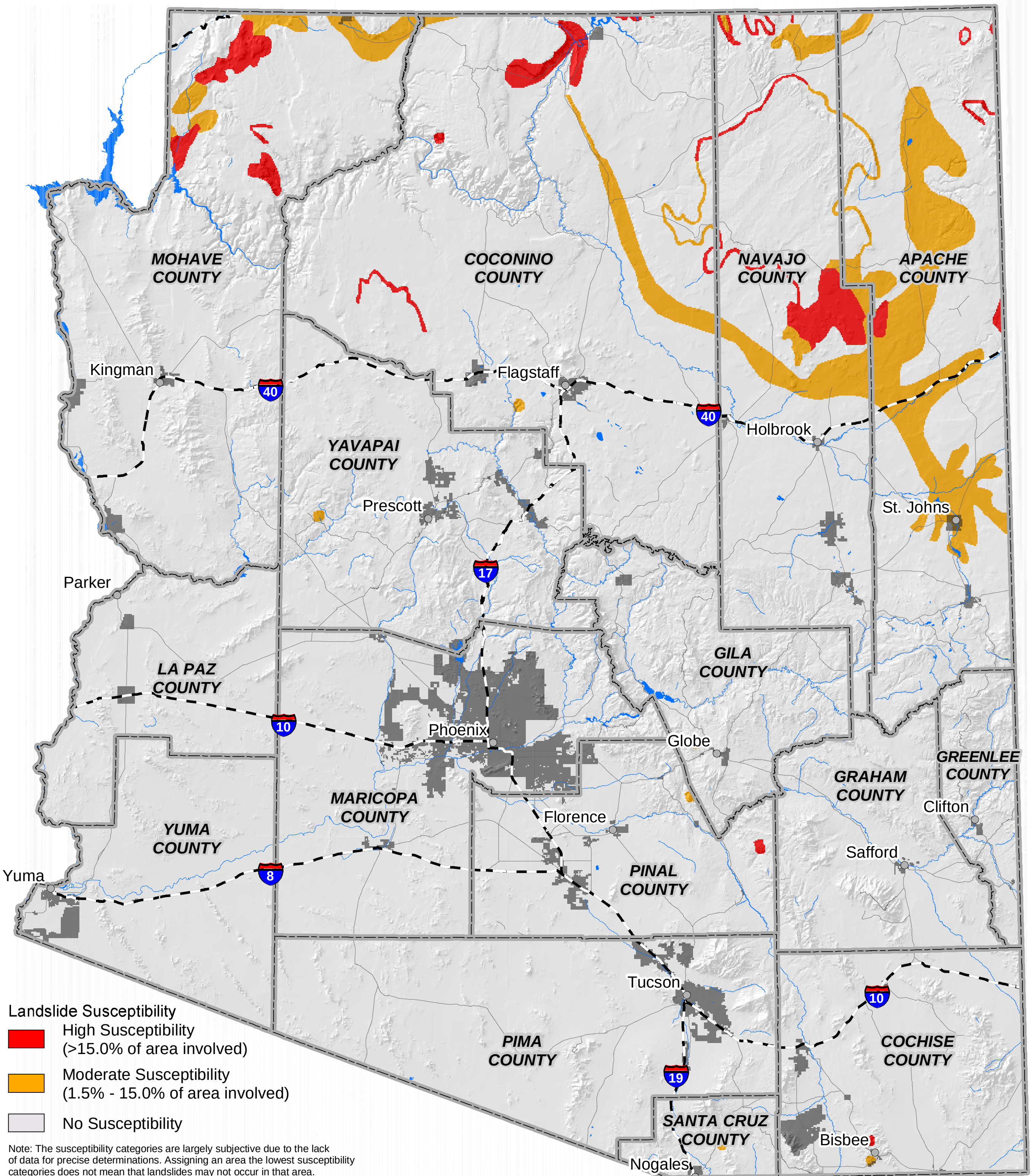
7.3.9.4 Warning Time

The goal of the USGS Landslide Hazards Program is to reduce long-term losses from landslides by improving our understanding of the causes of ground failure and suggesting mitigation strategies. The program has undertaken extensive research and disseminates information about landslide hazards in the U.S. The program also has numerous ongoing research projects, including real-time landslide hazard monitoring projects in areas of very high landslide risk, such as in the San Francisco Bay Area and in the Puget Sound area. The USGS has prepared a document titled, *National Landslide Hazards Mitigation Strategy – A Framework for Loss Reduction* (2000) and works together with the American Planning Association (APA) to assist communities in identifying and dealing with landslide hazards.

Even with the programs described above, the amount of warning time for a landslide event varies widely by the location, type, and size of event. Debris flows associated with prolonged rainfall are probably the most dangerous event type due to the high velocity of the event and they're potential for occurrence in areas not previously identified as posing landslide hazards. However, given their association with prolonged rainfall, such as from a tropical storm, it may be possible to identify and evacuate areas prior to their occurrence. Landslides that develop from earthquakes typically are manifest in the form of rock falls or topples which occur with little or no warning, and massive earthquakes may also cause widespread slides, flows, and lateral spreads.



Landslide Susceptibility

High Susceptibility (>15.0% of area involved)

Moderate Susceptibility (1.5% - 15.0% of area involved)

No Susceptibility

Note: The susceptibility categories are largely subjective due to the lack of data for precise determinations. Assigning an area the lowest susceptibility categories does not mean that landslides may not occur in that area. Also,due to the highly generalized nature of the map, it is unsuitable for local planning or site selection purposes.

(Source: HAZUS99, ALRIS July 2001, USGS 1997)

LEGEND

- Interstate
- Highway
- City
- Major Stream
- County
- Lake
- County Seat

N

0 25 50
Miles

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December 2003

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-19

Landslide Susceptibility in Arizona

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ARIZONA EMERGENCY MANAGEMENT

7.3.10 Lightning

7.3.10.1 Nature

Lightning typically occurs as a by-product of a thunderstorm. The action of rising and descending air in a thunderstorm separates positive and negative charges, with lightning the result of the buildup and discharge of energy between positive and negative charge areas. Water and ice particles may also affect the distribution of the electrical charge. In only a few millionths of a second, the air near a lightning strike is heated to 50,000°F, a temperature hotter than the surface of the sun. Thunder is the result of the very rapid heating and cooling of air near the lightning that causes a shock wave.

The hazard posed by lightning is significantly underrated. High winds, rainfall, and a darkening cloud cover are the warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the beginning of an approaching storm, more than half of lightning deaths occur after a thunderstorm has passed. The lightning threat diminishes after the last sound of thunder, but may persist for more than 30 minutes. When thunderstorms are in the area, but not overhead, the lightning threat can exist when skies are clear. Lightning has been known to strike more than 10 miles from the storm in an area with clear sky above.

According to the National Oceanic and Atmospheric Administration (NOAA), there are an average of 20 million cloud-to-ground flashes have been detected every year in the continental US. About half of all flashes have more than one ground strike point, so at least 30 million points on the ground are struck on the average each year. In addition, there are roughly 5 to 10 times as many cloud-to-cloud flashes as there are to cloud-to-ground flashes (NOAA, July 7, 2003).

Lightning is the most dangerous and frequently encountered weather hazard that most people in the US experience annually. Lightning is the second most frequent killer in the US, behind floods/flash floods, with nearly 100 deaths and 500 injuries annually. These numbers are likely to underestimate of the actual number of casualties because of the under reporting of suspected lightning deaths and injuries.

Cloud-to-ground lightning can kill or injure people by either direct or indirect means. The lightning current can branch off to strike a person from a tree, fence, pole, or other tall object. It is not known if all people are killed who are directly struck by the flash itself. In addition, their current may be conducted through the ground to a person after lightning strikes a nearby tree, antenna, or other tall object. The current also may travel through power or telephone lines, or plumbing pipes to a person who is in contact with an electric appliance, telephone, or plumbing fixture. Lightning may use similar processes to damage property or cause fires.

7.3.10.2 History

Nationally, lightning strikes rank second only to flash floods in weather-related deaths. Annually, lightning causes around 100 deaths in the U.S. NOAA undertook a major study of lightning-related fatality, injury, and damage reports in the US for the period 1954-1994, with the following findings (October 1998):

- There were 3,239 deaths, 9,818 injuries, and 19,814 property-damage reports from lightning. The number of lightning-caused casualty and damage events was less variable from year to year than other weather causes. For this reason, lightning is the most constant and widespread threat to people and property during the thunderstorm season.
- Florida led the nation in the actual number of deaths and injuries, while the largest number of damage reports came from Pennsylvania.
- Taking population into account, there were large variations among decades in casualties and damages, with New Mexico and Wyoming leading the nation in death, injury, and casualty rates. High casualty rates tended to be in Florida, the Rocky Mountains (including Arizona), plains, southeast, and New England. The highest rates of population-weighted damage reports were on the plains.

- During the study period, lightning in Arizona caused 59 fatalities, 105 injuries, and a164 damage reports. The state ranked 19th in the nation in terms of lightning strikes per person.

Similarly, the Centers for Disease Control (CDC) and Prevention studied lightning mortality and morbidity in the U.S. during the period 1980-1995, with the following findings:

- A total of 1,318 deaths were attributed to lightning, equating to an average of 82 deaths per year.
- The greatest number of deaths attributable to lightning occurred in Florida and Texas (145 and 91, respectively).
- Accounting for population, New Mexico, Arizona, Arkansas, and Mississippi had the highest lightning death rates, respectively, with 10.0, 9.0, 9.0, and 9.0 per 10.0 million population (CDC, October 5, 1998).

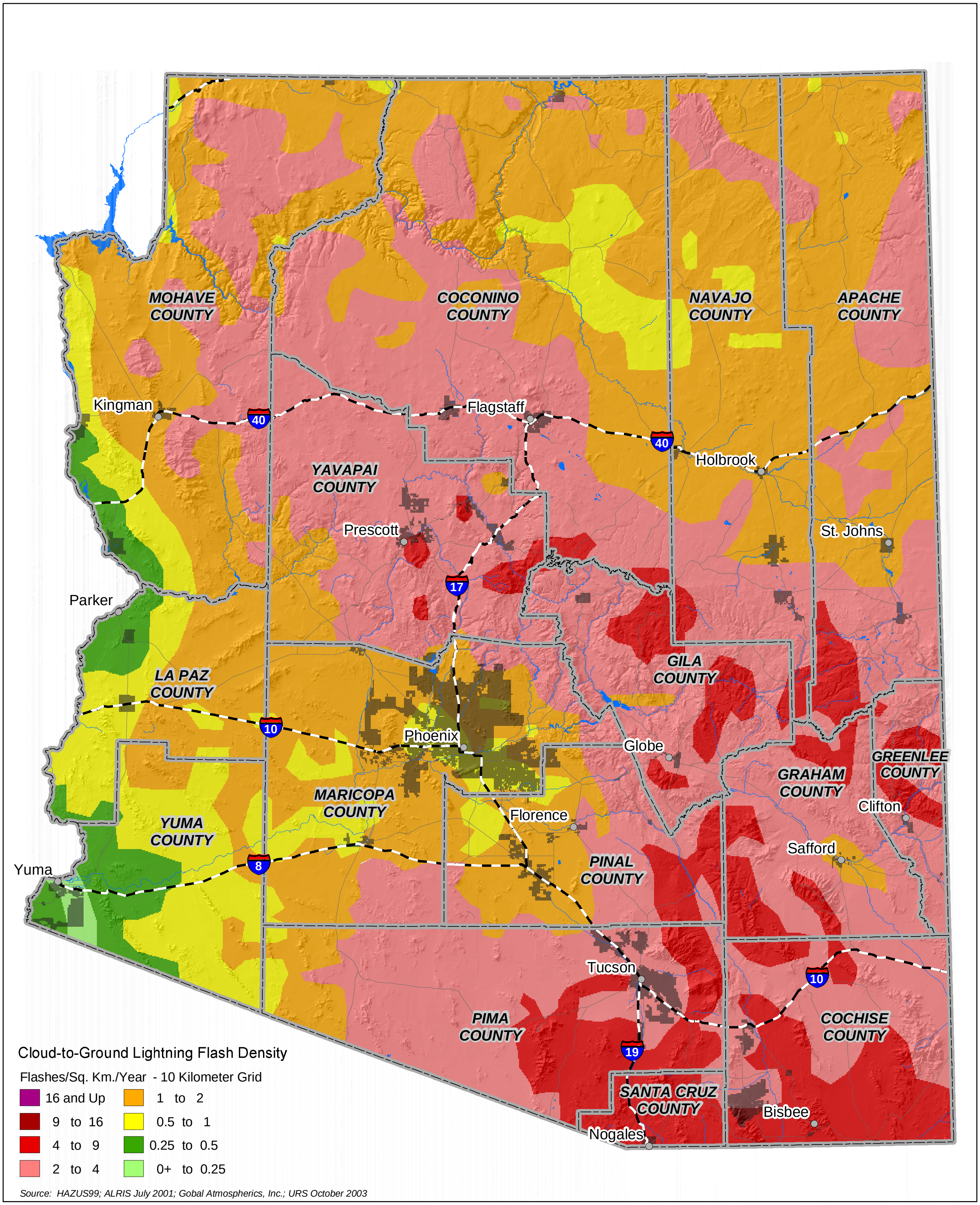
Using the NOAA Storm Event Database, a total of 48 significant lightning events in Arizona were identified, none of which prompted a disaster declaration, as shown in Table 7-3. Significant events include those with at least one death, one injury, or $50,000 worth of damage, or that were severe enough to have been identified in historical records. The 48 undeclared events resulted in 9 fatalities, 68 injuries, and $5.8 million in damages (one event accounted for $5.0 million in recorded damages). These events include the following:

- The first significant lightning event record was from July 24,1994. Lightning struck a man while hiking in the mountains 60 miles northeast of Sierra Vista in Cochise County, leaving him in a coma for two days before regaining consciousness. Three companions were knocked to the ground by the strike, and one sustained deep cuts to his face when he was thrown onto some jagged rocks.
- On September 2, 1994, during a severe thunderstorm that affected the entire Phoenix area, a 22-year-old man was killed by lightning while trying to retrieve his vehicle in a parking lot in Tempe.
- Ten people received minor injuries from a single lightning strike one mile east of Flagstaff, on August 12, 1995.
- On July 28, 1999, a cluster of severe thunderstorms moved west across the Phoenix metropolitan area, toppling and uprooting large trees, blew shingles off roofs, and downed power lines. Lightning also struck a manufacturing plant, and the resulting fire destroyed the building and its contents, causing total damages of $5.0 million.
- Four teenage boys were struck by lightning in Tucson on October 19, 2000, injuring three and leaving the other in critical condition.

7.3.10.3 Probability and Magnitude

The mean annual lightning strike density in Arizona is shown in Figure 7-20. Much of Arizona is subject to 4 or more lightning strikes per square kilometer annually. The highest density of lightning strikes is in the area between Flagstaff and the Grand Canyon in Coconino County, where there are 14-16 lightning strikes per square kilometer annually. Another area of concentration is in the southeastern corner of the state, where there are 12-14 lightning strikes per square kilometer annually.

The areal extent and density of lightning strikes is somewhat similar to that for maximum thunderstorm and tornado activity. Severe thunderstorms are likely to generate concurrent effects, such as lightning, severe winds, tornadoes, and hail.



LEGEND

Interstate — Highway

City — Major Stream

County — Lake

County Seat

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Miles

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December 2003

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-20

Lightning Flash Density in Arizona, 1996-2000

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7.3.10.4 Warning Time

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

Unfortunately, there is no universal answer for every storm event. Warning times vary based on storm location, direction, intensity, duration, and the topography and size of the drainage area. Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. Forecasters can't issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far ahead. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona emanate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

Lightning is a consequence of severe thunderstorms. The NWS issues a severe thunderstorm watch when conditions are favorable for the development of severe thunderstorms. The local NWS office considers a thunderstorm severe if it produces hail at least 3/4-inch in diameter, wind of 58 mph or higher, or tornadoes. When a watch is issued for a region, residents are encouraged to continue normal activities but should remain alert for signs of approaching storms, and continue to listen for weather forecasts and statements from the local NWS office. When a severe thunderstorm has been detected by weather radar or one has been reported by trained storm spotters, the local NWS office will issue a severe thunderstorm warning. A severe thunderstorm warning is an urgent message to the affected counties that a severe thunderstorm is imminent. The warning time provided by a severe thunderstorm watch may be on the order of hours, while a severe thunderstorm warning typically provides warning time in the range of an hour or less.

A severe thunderstorm watch may be issued by a NWS office to give advanced notice that severe thunderstorms are possible in an area, providing time to make preliminary plans for moving to a safe location if a severe thunderstorm warning is issued. A NWS office may issue a severe thunderstorm warning in order to urgently announce that a severe thunderstorm has been reported or is imminent in the area and that people should take immediate cover. The warning time provided by a severe thunderstorm watch may be on the order of hours, while a severe thunderstorm warning typically provides warning time in the range of an hour or less.

As noted previously, lightning strikes may occur in areas with clear skies, up to 10 miles from thunderstorms and before or after thunderstorm activity. Lightning strikes occur in millionths of a second.

7.3.11 Severe Winds

7.3.11.1 Nature

Wind is the motion of air relative to the surface of the earth. The most significant aspects of wind are the horizontal flow and the near-surface phenomena. Severe winds, also known as extreme winds or windstorms, are associated with tropical cyclones, winter cyclones, and severe thunderstorms and accompanying events, such as tornadoes, downbursts, and microbursts. Wind speeds vary from near zero at ground level to 200 miles per hour (mph) in the jet stream approximately six to eight miles above the earth (FEMA, 1997).

Wind speed is measured in many ways, such as peak gusts, fastest mile wind speed, 1-minute wind speed, 10-minute wind speed, sustained wind speed, and gradient wind speed. The main factors in all wind speed measures are the following:

- Duration: The shorter the period over which the wind is measured, the higher the wind speed due to the affect of gusts.
- Altitude: Wind speed increases with altitude to a certain extent, after which wind speed becomes constant. The height over which the wind speed increases is called the boundary layer, with gradient wind speed measured above the boundary layer.
- Terrain: Wind speeds over smooth surfaces (e.g., fields, water) are much higher than over rough surfaces (e.g., cities, rough terrain).

In the mainland US, the mean annual wind speed is 8 to 12 mph, with frequent wind speeds of 50 mph, and occasional speeds of more than 70 mph. Tropical cyclone winds on the East and Gulf Coast may exceed 100 mph. Foehn-type winds are regional down slope winds in mountainous regions (e.g., Rocky Mountains, Southern California) that may exceed 100 mph in small areas and for short periods. In addition, severe thunderstorms often produce wind downbursts, microbursts, and tornadoes. These events are often interrelated, making it difficult to separate the individual wind components that cause damage.

Near-surface winds and their associated pressure effects (positive and negative) exert pressure on structural components, such as the walls, doors, windows, and roof. Positive wind pressure directly pushes the components inward, while negative pressure indirectly creates lift and suction forces that pull the components outward and upward. The upper levels of multi-story structures are subject to magnified effects. In addition to the pressure effects, internal building pressures rise and result in the failure of roof or leeward structural components. In addition, debris carried by extreme winds causes additional damage to structures and people.

7.3.11.2 History

The entire U.S. is vulnerable to the hazards of windstorms, including hurricanes, severe thunderstorms, tornadoes, downbursts, and microbursts. In 1998, a calm year according to experts, wind related storms resulted in more than $5.5 billion in damages, and at least 186 fatalities (ASCE, May 9, 2003).

A total of only five distinct severe wind events in Arizona were identified, none of which prompted a disaster declaration, as shown in as shown in Table 7-3. It is important to recognize, however, the interrelated nature of severe winds and other significant severe weather events that Arizona has experienced in high numbers. For example, a combined total of 215 thunderstorm, tornado, and tropical storm events were recorded, with a combined total of 46 fatalities, 378 injuries, and $854 million in damages, as shown in as shown in Table 7-3.

The five undeclared significant severe wind events resulted in a reported one fatality, one injury, and $30,000 in damages. These events include the following:

- In August 1945, a storm accompanied by severe winds caused extensive damage in Mesa.
- In December 1945, one person was killed by a falling tree in Mesa that was knocked over by severe winds.

- On July 25, 1996, severe winds associated with a microburst caused extensive wind damage throughout Maricopa County, including knocking down 60-foot power poles in Queen Creek and damaging aircraft and hangars at the Chandler airport.

7.3.11.3 Probability and Magnitude

There are various methods of measuring and displaying the probability and magnitude of wind speeds. These measures are used by organizations to make recommendations concerning the minimum building code standards in areas subject to varying wind speeds in order to reduce the potential for damage to structures and injuries to people.

A traditional wind speed measure is the fastest mile wind speed, which measures the highest wind speed measured at an altitude of 33-feet in open terrain. Technically speaking, it is the period of time required for one mile of wind to pass the anemometer, an instrument for measuring wind force and velocity. The measure is made over smooth terrain (e.g., flat open country and grasslands), with an annual probability of 2.0 percent (equivalent to a return period of 50-years).

The fastest mile speed has more recently been replaced by the 3-second wind gust speeds which is considered by the American Society of Civil Engineers (ASCE) to more accurately measure the potential for damage to structures. According to this measure, the 3-second gust wind speed for most of the US is 90 mph, with 3-second gust wind speeds for the East and Gulf Coast areas, including an area of 150-165 mph at the southern tip of Florida (ASCE, 1999).

Most of Arizona has a 3-second gust wind speed of 90 mph, as shown in Figure 7-21, indicating relatively low levels of risk from severe winds. However, parts of Coconino and Navajo Counties have been designated a special wind region which should be examined for unusual wind conditions and special considerations may be warranted, such as consultation with a wind engineer and additional measures specified in local building codes.

Likewise, FEMA identifies most of Arizona in design wind speed Zone I. In this zone, a design wind speed of 130 mph is recommended for the design and construction of community shelters. FEMA also specifies the same special wind region covering parts of Coconino and Navajo counties (FEMA, July 2000).

The maximum and average wind speeds in selected cities in Arizona are displayed in Table 4-5. Tucson has the highest recorded wind speed with 71 mph. Winslow and Yuma also have fairly high maximum wind speeds with, respectively, 63 and 61 mph. Flagstaff and Phoenix have significantly lower maximum wind speeds with, respectively, 46 and 43 mph. The average wind speeds in these cities are much lower, ranging from 6.2 to 8.8 mph.

7.3.11.4 Warning Time

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

Unfortunately, there is no universal answer for every storm event. Warning times vary based on storm location, direction, intensity, duration, and the topography and size of the drainage area. Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. Forecasters can't issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far ahead. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona emanate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

Severe winds are typically a consequence of tropical cyclones, winter cyclones, and severe thunderstorms and accompanying events, such as tornadoes, downbursts, and microbursts. The NWS issues a severe thunderstorm watch when conditions are favorable for the development of severe thunderstorms. The local NWS office considers a thunderstorm severe if it produces hail at least 3/4-inch in diameter, wind of 58 mph or higher, or tornadoes. When a watch is issued for a region, residents are encouraged to continue normal activities but should remain alert for signs of approaching storms, and continue to listen for weather forecasts and statements from the local NWS office. When a severe thunderstorm has been detected by weather radar or one has been reported by trained storm spotters, the local NWS office will issue a severe thunderstorm warning. A severe thunderstorm warning is an urgent message to the affected counties that a severe thunderstorm is imminent. The warning time provided by a severe thunderstorm watch may be on the order of hours, while a severe thunderstorm warning typically provides warning time in the range of an hour or less.

7.3.12 Subsidence

7.3.12.1 Nature

Land subsidence is the loss of surface elevation and affects nearly every U.S. state. Land subsidence has numerous causes, although the primary causes are underground coal mining, groundwater and petroleum withdrawal, and the drainage of organic soils. Due to the diversity of causes and wide range of impacts, land subsidence has been analyzed primarily by federal, state, and local agencies independently, with comparatively little focus nationally (FEMA, 1997).

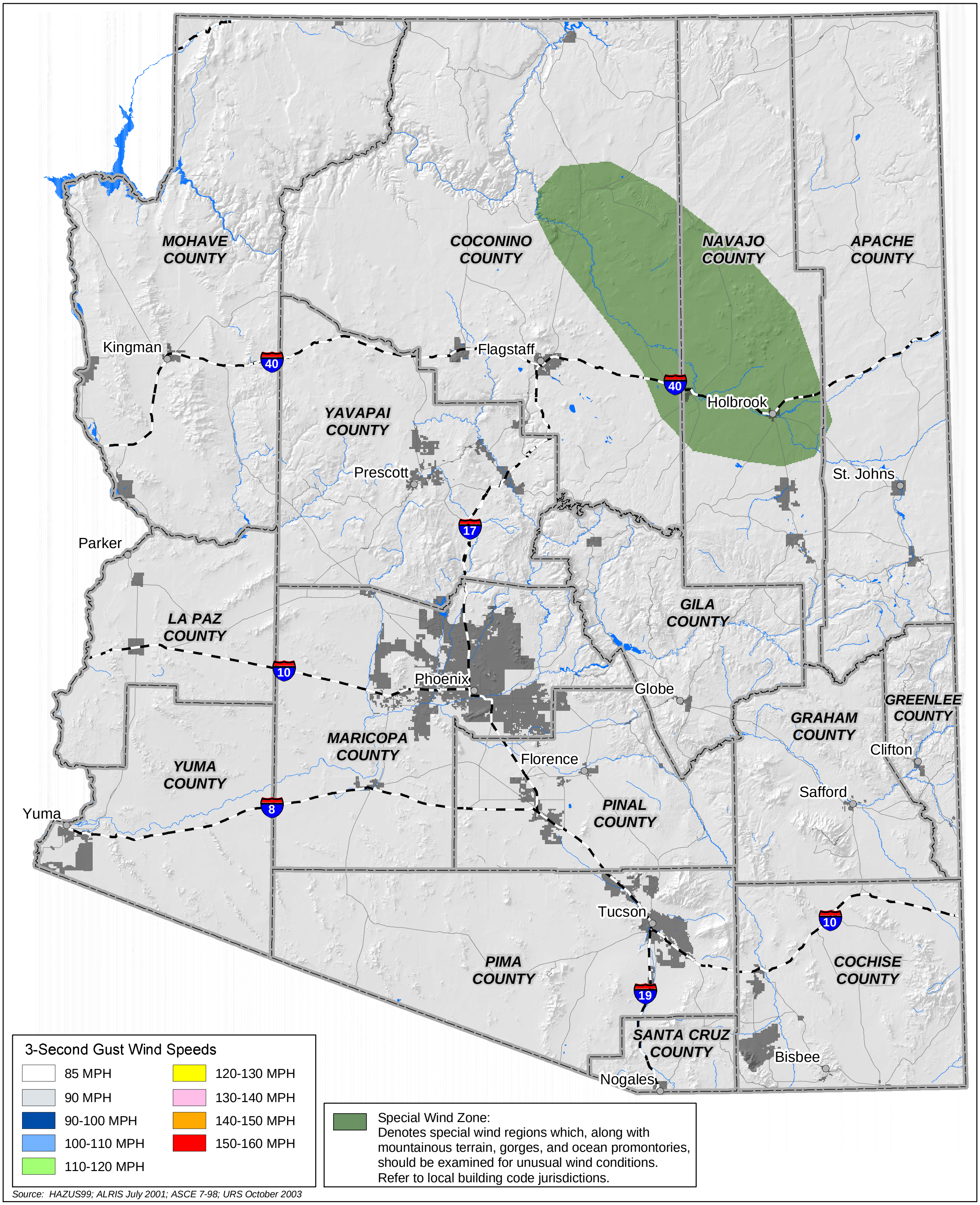
Land subsidence is caused by numerous human activities and natural processes including the following: mining of coal, metallic ores, limestone, salt, and sulfur; withdrawal of groundwater, petroleum, and geothermal fluids; dewatering of organic soils; wetting of dry, low-density deposits known as hydrocompaction; natural sediment compaction; melting of permafrost; liquefaction; and crustal deformation. Land subsidence takes three major forms:

- Collapse Into Voids: The collapse of surface materials into underground voids is the most dramatic form of land subsidence and is most frequently caused by coal mining. While typically collapses are human-caused, some cavities may be natural, such as in limestone or halite. Catastrophic subsidence is most commonly caused by lowering of the water table, rapid water table fluctuation, diversion of surface water, construction, use of explosives, or impoundment of water.
- Sediment Compaction: Typically causing broad regional subsidence or a few millimeters per year, total subsidence due to sediment compaction may reach several meters over decades. Sediment compaction is the result of underground fluid withdrawal, natural compaction, or hydrocompaction,
- Drainage of Organic Soils: The draining of organic soils, such as peat and muck, causes a series of processes that reduce the volume of soil. This primarily affects large wetlands or river delta areas.

Subsidence is primarily an economic hazard, threatening buildings and infrastructure, as opposed to a threat to life. It may also lead to cracks in the earth's surface called fissures, which themselves are also hazardous.

7.3.12.2 History

Land subsidence is estimated to affect parts of at least 45 states. More than 17,000 square miles of land has been lowered due to subsidence, an area roughly the size of New Hampshire and Vermont combined. More than 80 percent of the identified subsidence nationally has been due to the removal of underground water. In 1991, the National Research Council (NRC) estimated that the cost of flooding and structural damage from land subsidence in the U.S. exceeded $125 million annually. The estimation of less direct or hidden costs is complicated by difficulties identifying and mapping affected areas, establishing cause and affect relationships, assigning economic values to environmental resources, and inherent legal system conflicts. As a result, the annual total cost of subsidence is probably significantly larger (USGS, 1999).



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- City
- Major Stream
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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-21
Severe Wind Hazard Areas in Arizona

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In 1991, the NRC estimated cumulative damages from subsidence by type for U.S. states. While broad ranges were used for these estimates, they provide an indication of the relative hazard level posed by different types of subsidence. According to the NRC, underground fluvial withdrawal (i.e., withdrawal of underground water) is clearly the largest subsidence hazard in Arizona, with $10-100 million in estimated cumulative damages in 1991, as shown in Table 7-20. Relatively minor subsidence damage was posed by mining and hydrocompaction, with $0-1 million in cumulative damages each.

In south-central Arizona, the approximately lower two-thirds of the state, the combination of low rates of precipitation (3-20 inches per year) and high rates of evapotransportation (60+ inches per year) has historically led to high rates of groundwater withdrawal. Groundwater withdrawal in Arizona began before 1900 and was used largely for irrigation. By the 1960's, increasing development and declining groundwater levels led to the approval of the Central Arizona Project (CAP) Canal, which provided approximately 12 percent of Arizona's water in 1994 (see Table 7-7). That same year, however, groundwater accounted for 44 percent of water used in Arizona.

Table 7-20: Estimated Cumulative Damage From Subsidence by Type in Arizona, 1991

Subsidence Type	Cumulative Damage (mill.)
Mining	$0-1
Sinkholes	$0
Underground Fluid Withdrawal	$10-100
Hydrocompaction	$0-1
Organic Soils	$0

Note: Costs not converted into constant dollars. Figures can be used as a general measure of risk associated with land subsidence, but do not indicate probability or magnitude of land subsidence.

Source: FEMA, 1997 (from National Research Council, 1991).

The withdrawal of groundwater is the primary cause of land subsidence and earth fissures that affect significant portions of south-central Arizona. The areas of greatest subsidence correspond to the areas of greatest groundwater level decline (USGS, 1999). One subsidence hazard event has been identified for Arizona that led to damages, as shown in Table 7-3:

- On Luke Air Force base in Glendale, Maricopa County, up to 18 feet of subsidence and related earth fissures have been recorded. This led to a significant increase in local flooding and the flow reversal of the Dysart Drain, an engineered flood control device. On September 20, 1992,a rainstorm caused 4 inches of surface runoff that closed the base for 3 days. The Dysart Drain spilled over due to sluggish flow, flooding the runways and 100 homes, resulting in approximately $3 million worth of damages (USGS, 1999).

In addition, other major areas of subsidence in Arizona identified by the USGS are shown in Figure 7-22 and include the following:

- Eloy, Pinal County, around which 625 square miles were recorded as having subsided up to 12.5 feet around by 1977.
- Around Stanfield, Pinal County, 425 square miles of subsidence was recorded as having subsided up to 11.8 feet by 1977.
- Near Queen Creek, Maricopa County, an area of nearly 230 square miles was recorded as having up to 3 feet of subsidence.
- In northeast Phoenix, Maricopa County, up to 5 feet of subsidence was measured from 1962-1982.

- Near Willcox, Cochise County, up to 5 feet of subsidence was recorded.
- On the Harquahal Plain, La Paz County, only 0.6 feet of subsidence was recorded.

Earth fissures, long linear cracks at the surface that have little or no vertical offset, often occur in alluvial valley sediments in areas of subsidence in Arizona. Prior to 1980, more than 50 areas of fissures were mapped in Arizona. Fissures may start out only fractions of an inch wide and several hundred feet long. However, they may increase to 30 feet wide, thousands of feet long, and more than 30 feet deep. The most studied fissure in Arizona is the Picacho earth fissure, shown in Figure 7-22. This fissure has caused damage to Interstate 10, a change to the route of the CAP Canal, and exposed a natural gas pipeline.

The Arizona Department of Water Resources (ADWR) is working with the Center for Space Research at the University of Texas, Austin, to research land subsidence in Arizona. The research uses radar interferometry to measure land subsidence in Phoenix, Arizona and Houston, Texas. Radar interferometry is a technique where radar data, usually recorded from satellite, are used to map the elevation (topography) or the deformation of the ground - such as in earthquakes or subsidence. The research is sponsored by the following: NASA's Earth Science Enterprise, Solid Earth and Natural Hazards program; European Space Agency; Western North America InSAR Consortium; and ADWR.

The use of several interferograms spanning different time periods provides information about the spatial and temporal progression of subsidence in these regions. From this work, it is possible to identify those areas in central Arizona that are experiencing subsidence at a rate of 0.5 cm/year or more. As shown in Figure 7-22, Maricopa County has two major areas of subsidence, one in the northwest and one in the northeast. The northwest subsidence area is centered on Sun City, but also affects parts of El Mirage, Glendale, Peoria, Phoenix, Surprise, and Youngtown. In the northeast, parts of Phoenix and Scottsdale area affected. In Pima County, an area in northeast Tucson is also affected.

7.3.12.3 Probability and Magnitude

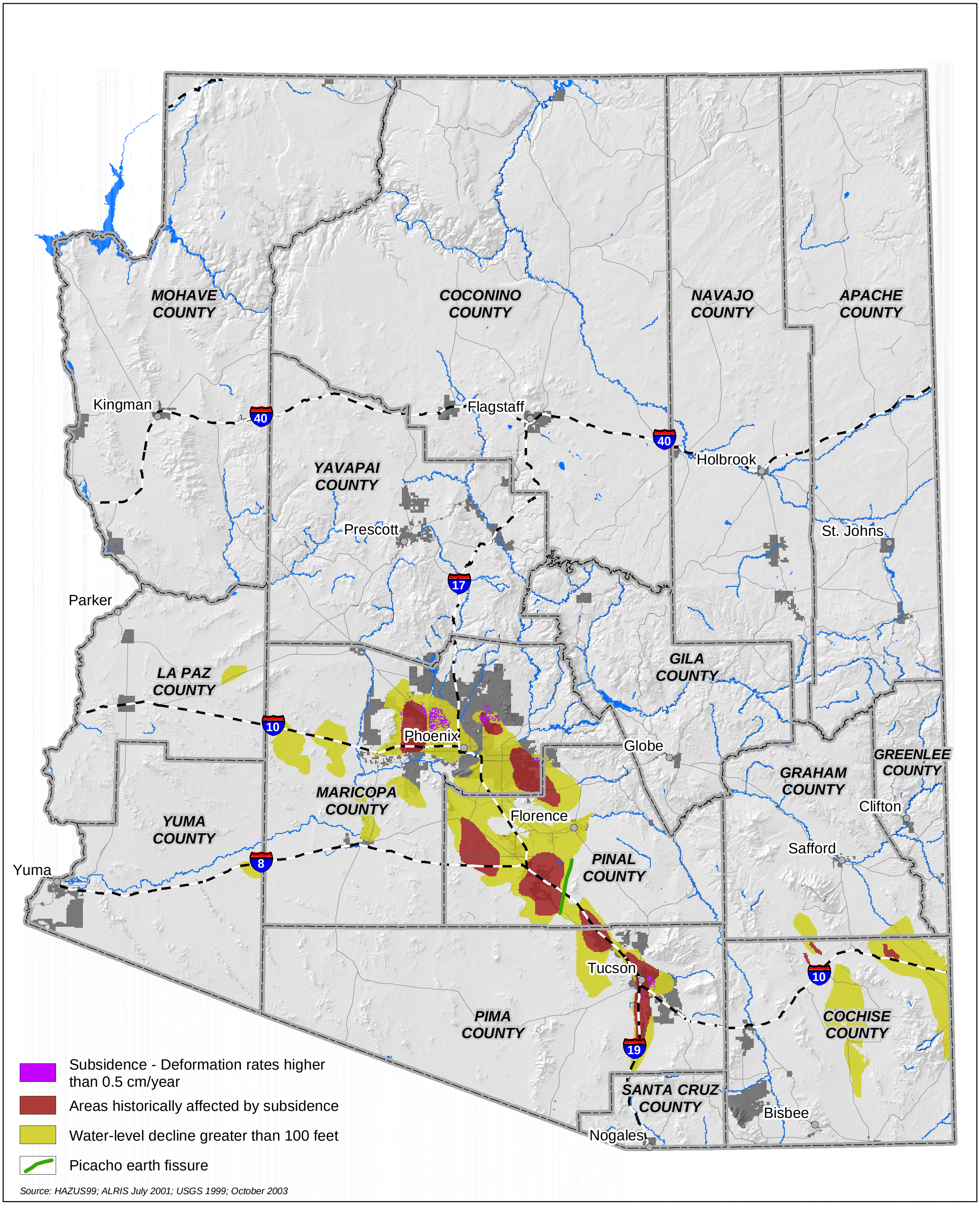
Procedures to determine the probability and magnitude of land subsidence have not been recommended. However, the major areas of subsidence in Arizona identified by the USGS shown in Figure 7-22 have historically been subject to subsidence and may be considered to be susceptible to subsidence in the future. The magnitude of subsidence is difficult to determine in advance, although it may be reasonable to expect that those areas shown via interferograms to be subsiding at a rate of 0.5 cm/year or more will continue to do so in the future.

7.3.12.4 Warning Time

Subsidence is a hazard that typically happens slowly, over a period of months, years or decades. As such, significant warning time should be available to prepare for, and ever avoid, subsidence.

These warnings may come from the National Geodetic Survey (NGS) which develops and maintains a national system of positioning data needed for transportation, navigation, and communication systems; land record systems; mapping and charting efforts; and defense operations. The foundation of the system is the National Spatial Reference System (NSRS), which is a national coordinate system that defines position (latitude, longitude and elevation), distances and directions between points, strength of gravitational pull, and how these change over time. This system includes work on a set of models that predict geophysical processes such as land subsidence (sinking) and uplift, movement of the Earth's crust, and other phenomena affecting spatial measurements.

The radar interferometry research of the ADWR and Center for Space Research described above may also provide such warnings.



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- Highway
- Major Stream
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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-22

Areas Historically Affected by Subsidence in Arizona

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7.3.13 Terrorism

7.3.13.1 Nature

The *Disaster Mitigation Act of 2000* grew out of a focus on planning for natural hazards. However, recent events suggest that mitigation plans should also address hazards generated by human activities, such as terrorism and hazardous materials accidents. Specifically, the need to incorporate new threats into emergency management planning—including human-caused hazards such as terrorism and technological disasters—has become all too apparent, as demonstrated by the September 11, 2001 attacks on New York City and Washington, D.C., and the July 2001 hazardous material train derailment and fire in Baltimore, Maryland. Additionally, the 2001 anthrax attacks, the 1996 bombing at the Summer Olympics in Atlanta, the 1995 destruction of the Murrah Federal Building in Oklahoma City, the 1993 World Trade Center bombing, and scores of smaller-scale incidents and accidents reinforce the need for communities to reduce their vulnerability to future terrorist acts and technological disasters (FEMA, September 2002).

Terrorism can take many forms, including the following:

- Agriterrorism
- Arson/incendiary attack
- Armed attack
- Biological attack
- Chemical agent
- Cyberterrorism
- Conventional bomb
- Hazardsous material relesease (intentional)
- Nuclear bomb
- Radiological agent.

While the term “mitigation” refers generally to activities that reduce loss of life and property by eliminating or reducing the effects of disasters, in the terrorism context it is often interpreted to include a wide variety of preparedness and response measures. Historically, the role of counterterrorism has been viewed to be the sole province of law enforcement, defense, and intelligence officials. Furthermore, defensive efforts to protect people and facilities from terrorism were generally limited to the government sector, the military, and some industrial interests. However, both technological disasters and incidents of domestic and international terrorism in the United States during the past decade have made it clear that emergency managers, first responders, and planners must now work together to build better and safer communities in the 21st century.

7.3.13.2 History

In Arizona, the traumatic events of September 11, 2001 catalyzed a more dynamic and inclusive effort to address the threat of terrorism in the state. Immediately following the attacks of 9/11, the State of Arizona relied upon a pre-existing emergency response infrastructure established in the late-1990’s as the foundation of its homeland security efforts. This infrastructure included the following:

1. In 1997, the Division of Emergency Management (DEMA) worked with the Department of Public Safety (DPS) to establish the Domestic Preparedness Task Force. The group consists of representatives from more than 40 public and private entities which meet regularly to review response and recovery plans.

2. The State of Arizona also established a State Emergency Operations Center (EOC) within DEMA that can be fully activated within an hour (as it was during 9/11). The EOC brings together all relevant public and private entities to address emergency situations.

3. In February 1998, DEMA produced an Emergency Response and Recovery Plan for the State of Arizona. The plan was developed to be comprehensive and detailed, broken down by the responsibilities of each agency. It was also intended to be practiced prior to an emergency situation so that it could be implemented in the event of an actual crisis.

Immediately after the tragedy, Arizona took additional steps to bolster its emergency preparedness. The Department of Public Safety activated its Domestic Preparedness Operations Center and established a 24-hour tip line for individuals to report suspicious activities and concerns. Additionally, DPS created a secured website as a vehicle to share information with local, county and other authorities, dedicated additional intelligence analysts and investigators to collect and analyze terrorism related information and appointed additional personnel to the FBI's Joint Terrorism Task Force.

The U.S. Attorney General instructed each U.S. attorney to establish an anti-terrorism task force. Arizona's consists of members from various state and local law enforcement agencies. The Arizona National Guard in Phoenix and Tucson began flying support missions for air combat patrols, troops were sent to protect Hoover Dam and traffic was routed away from the site. Two hundred fifty guard personnel were sent to ten airports around Arizona to provide increased surveillance, and additional guard personnel were sent to secure the perimeter of the Palo Verde nuclear facility. In the months following, state, local and federal law enforcement agencies coordinated to provide enhanced security for the World Series and to send National Guard units to assist at four major border crossings. To organize the state's efforts, then-Governor Jane Dee Hull in 2001 appointed two members of her staff to coordinate Homeland Security and formed a Homeland Security Coordinating Council. The goal of the council was to oversee all homeland security activities at state agencies and also to develop and implement homeland security policies.

Upon taking office in January 2003, Governor Janet Napolitano announced that efforts to detect, prevent and respond to acts of terrorism would be one of her administration's priorities. Governor Napolitano immediately took a number of steps including appointing an Interim Homeland Security Director to develop a plan for how the state would handle homeland security.

Today, terrorism prevention initiatives in Arizona are guided largely through "Securing Arizona, A Roadmap for Arizona Homeland Security", which was finalized in April of 2003. Through this initiative various aggressive action items were proposed which would assist the state in preventing terrorist action and mitigating the impact of such an event. Specifically:

1. The State of Arizona will take steps to establish a statewide integrated justice system that links the information systems used by federal, state, local and tribal criminal justice entities (police, corrections, courts, etc.) in such a way to support the identification of emerging terrorism related trends.

2. The state will establish a 24/7 intelligence information analysis center that will serve as a central hub to facilitate the collection, analysis and dissemination of crime and terrorism related information.

3. Arizona will take steps to establish a statewide disease surveillance system that collects information from emergency rooms, physicians, animal control entities, pharmacies, public safety entities and other relevant public and private sector entities to identify emerging public health problems such as naturally occurring diseases, environmental problems, biological and chemical weapons attacks.

Supplementing the Securing Arizona initiative is the State Homeland Security Strategy (SHSS), which was completed in December of 2003. This document establishes as a goal, "To protect all of Arizona's citizens from potential terrorist attack and enhance the response and recovery capabilities of communities, whether urban or rural." Among the objectives supported through this document are the continued management and support for an anti-terrorism network that ensures that the proper resources, facilities, organization, plans and procedures, and training are all available to those responsible for preventing and responding to terrorist incidents.

Furthermore, the State Homeland Security Strategy provides that the State of Arizona will apply the resources available from the Department of Homeland Security (DHS) through the Office for Domestic Preparedness (ODP) to support planning, equipment, training, and exercise needs of the State in building an enhanced and sustainable capacity to prevent, respond to and recover from threats or acts of terrorism that may involve the use of a weapons of mass destruction. The Strategy also ensures that the State of Arizona will be able to detect, mitigate, prepare for, respond to, and recover from a terrorism incident. Any subsequent plans are intended to utilize an all hazard approach. In addition, Arizona's approach to enhancing regional capability and capacity to prevent and reduce the vulnerability of Arizona from weapons of mass destruction or terrorism incidents will be multidisciplined.

Among the many agencies involved in this massive mitigation effort will be the Arizona Division of Emergency Management (ADEM) and Office of Homeland Security (OHS), which will be responsible for the administration of the State Homeland Security Assessment and Strategy (SHSAS) program. The Governor's Homeland Security Coordinating Council (HSCC) will be responsible for review of these activities before going to the Governors office for final approval.

The Governors HSCC is a multidisciplined committee developed in order to help guide the strategy development process for equipment allocation and distribution among emergency responders in the state. This committee included representatives from law enforcement, emergency management, fire service, governmental administrative, tribal nations, and private sector and volunteer organizations assisting in disaster recovery.

7.3.13.3 Probability and Magnitude

Procedures to determine the probability and magnitude of terrorist attacks have not been established and it is beyond the scope of this plan to attempt to make estimates for the State or its communities. Generally, the severity of terrorist incidents depends upon the type of method used, the proximity of population and other assets, and the duration of exposure to the attack. For example, hazardous materials (e.g, Extremeley Hazardous Substances) have increasingly toxic effects on people, animals, and plants with proximity and exposure time.

Note that numerous federal, state, county, and local agencies are involved in the evaluation of the probability and magnitude of terrorist attacks, such as the U.S. Department of Homeland Security (which includes the Federal Bureau of Investigations, Federal Emergency Management Agency, and Office for Domestic Preparedness), Arizona Office of Homeland Security, Arizona Department of Public Safety, and Arizond Department of Emergency and Military Affairs. These agencies are involved in the constant evaluation of potential terrorist attacks, including the identification and monitoring of specific threat elements, identification and securing of potential targets (including population, buildings, facilities, and systems), the protetion of potential targets, and preparation for response in case of terrorist attack. For security reaons, additional information on the potential probability and magnitude of a terrorist attack, particularly for specific threats and targets, must be provided by the agencies noted above.

7.3.13.4 Warning Time

The nature of terrorism typically results in very little warning time prior to an attack. This is due to the numerous uncertainties regarding the nature of the threat, the selected target, and the inherent nature of a terrorist attack. Again, for security reaons, additional information on warning time related to a terrorist attacks, particularly for specific potential threats and targets, must be provided by the agencies noted above.

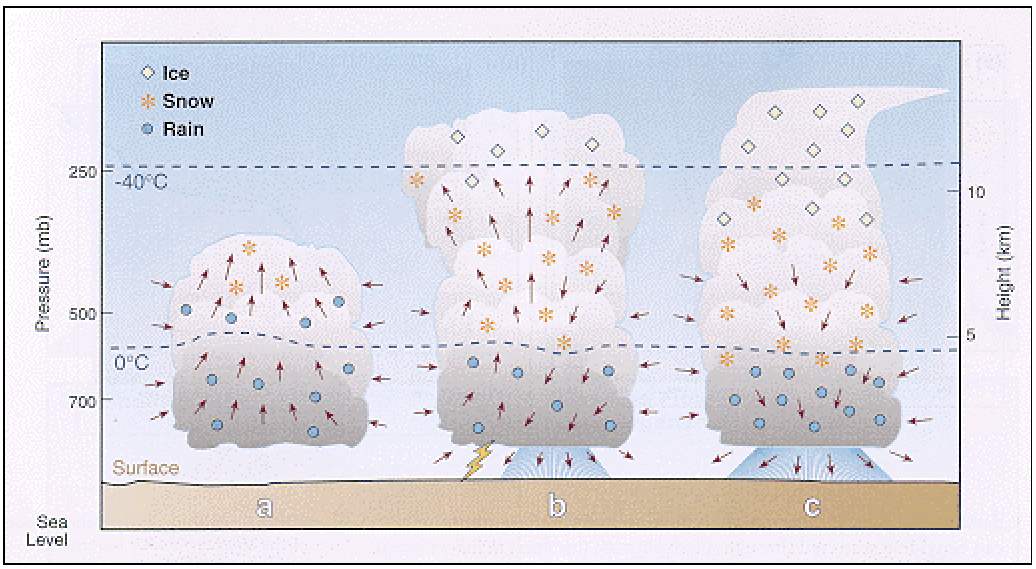
7.3.14 Thunderstorm

7.3.14.1 Nature

A thunderstorm, also known as a thunder event, is a local storm that produces lightning, thunder, and rainfall. A thunderstorm may consist of a single cumulonimbus cloud, a cluster of clouds, or a line of clouds, which is formed when moist, unstable air near the surface is lifted, as may occur due to strong surface heating, upward terrain, or the convergence of surface winds. The duration of a thunderstorm is measured as the time between the first peal of thunder, caused by lightning, and the last peal of thunder, with most storms lasting from 15 minutes to several hours. Compared with other atmospheric hazards, such as tropical storms and winter storms, most thunderstorms are relatively small (15 miles in diameter) and last for a short time at a single location (30 minutes). However, thunderstorms may intensify into severe thunderstorms capable of causing significant damage and able to travel significant distances (FEMA, 1997).

Thunderstorms typically have a three-stage life cycle, as illustrated in Figure 7-23. In the first state, known as the cumulus stage, warm, moist air rises and water vapor condenses, releasing latent heat which enhances the upward convection and the growth of the cloud. As the cloud rises and cools, it eventually passes above the freezing level, where supercooled water droplets and ice crystals coexist. In the second stage, the mature stage, both updrafts and downsdrafts exist within the cloud. Falling precipitation initiates downdrafts, although precipitation may evaporate before reaching the ground. Cloud to ground lightning usually begins when precipitation first falls from the base of the cloud. An anvil, or overhang of the top of the cloud may be visible at this stage. Finally, in the third or decaying stage, downdrafts dominate the cloud. Here the cloud has lost updrafts due to the release of latent heat and most of the water vapor has crystallized into frozen droplets that the cloud is no longer able to support. Precipitation may be heavy at this stage.

Figure 7-23: Thunderstorm Life Cycle



Source: National Weather Service Flagstaff.

Thunderstorms are categorized as ordinary and severe, with the latter meeting one of the following National Weather Service (NWS) criteria: winds reaching or exceeding 58 mph; production of a tornado; or hail at least 0.75 inches in diameter. Severe thunderstorms may also produce heavy precipitation, flash flooding, downbursts, and microbursts. Downbursts are strong, straight-line winds created by falling rain and sinking rain that may reach speeds of 125 mph. Microbursts are more concentrated than downbursts, with speeds reaching up to 150 mph. Both downbursts and microbursts typically last only 5-7 minutes, but can cause severe damage and pose a major hazard to aircraft departures/landings due to the wind shear and detection difficulties (FEMA, 1997).

Dangerous and damaging effects of severe thunderstorms include lightning, tornadoes, hail, flash flooding, and severe winds. In addition to the information presented on these in this section, each of these effects is treated in more detail in other sections contained in this document.

7.3.14.2 History

Since 1986, severe thunderstorm winds have killed over 300 people and injured over 4,000 nationwide. Of the estimated 100,000 thunderstorms that occur each year in the United States, only about 10 percent are classified as severe (NWS Flagstaff).

A total of 170 significant thunderstorm events were identified in Arizona, 14 of which prompted a disaster declaration, as shown in as shown in Table 7-3. These events caused at least one injury, one death, $50,000 worth of damage, or were severe enough to be identified in historical records. This is the second highest number of significant events, behind wildfires. It should be noted that the events detailed in this section are all associated with thunderstorms in some fashion, but may also appear as a significant event in another hazard profile. For example, the microburst that occurred on August 14, 1996 involved various documented severe weather events including damage caused by high wind, flooding, and hail. Specific event histories of these hazards are provided throughout the various chapters of this document. Most of the significant thunderstorm events were identified using the National Climate Center (NCDC) Storm Event Database, which has a large number of well-recorded events from approximately 1970 forward. For all 170 events, 18 deaths, 193 injuries, and $430.2 million in damages were recorded. These events include the following:

- On July 18, 1959, 10 people were injured and $1 million in damages caused by a severe thunderstorm in Mesa (Mesa Tribune).
- Severe thunderstorms were accompanied by heavy precipitation that caused flooding throughout Phoenix and Scottsdale, on June 15, 1972. The storms caused two fatalities, $8 million in damage from flooding, and led to a Gubernatorial emergency declaration (ADEM, March 6, 2003).
- On July 29, 1985, a severe thunderstorm in Maricopa County injured 12 people (NCDC Storm Event Database).
- A severe thunderstorm on August 27, 1988 caused two deaths and injured 17 in Pinal County (NCDC Storm Event Database).
- In Gila County, on June 26, 1990, a severe thunderstorm caused six fatalities (NCDC Storm Event Database).
- On August 5, 1993, a severe thunderstorm in Avondale resulted in 1 injury and $5 million worth of damages. Strong winds from nearby thunderstorms exceeded 50 mph in many areas of the Valley. Homes and businesses sustained damage, trees were uprooted and power lines were downed. Arizona Public Service reported 10,000 customers without power. An 8-year-old boy in Avondale was severely injured after a window burst and glass cut his jugular vein. The roof of a convenience store was blown off, as well as some damage to a church and an elementary school. A 1-mile section of a 69,000-volt power line near Perryville was knocked down. High winds blew tree limbs onto power poles and took shingles off several homes (NCDC Storm Event Database).
- In Tucson, roofs were blown off, trees uprooted, and power interrupted to some 20,000 customers on August 9, 1993. Power poles were snapped by high winds on the west side of the city. Winds reached as high as 60 mph at the NWS in Tucson. A total of $5.0 million property damage was recorded (NCDC Storm Event Database).
- September 12, 1993, a severe thunderstorm moved into the far northern part of the city of Casa Grande, and overturned a mobile home which pinned a small child underneath (the little girl later died of her injuries). The very strong thunderstorm winds also downed power lines and blew down a medium-size pine tree. Heavy rains also flooded part of Interstate 10 near milepost 190, and a subdivision had to be cordoned off due to high waters. There were also 2 injuries and $500,000 property damage(NCDC Storm Event Database).
- A microburst struck a school building at the Littleton Elementary School in the community of Cashion, two miles SW of Tolleson on September 13, 1994. The roof was torn off about eight classrooms with

one teacher and eight children being injured. A NWS Storm Survey Team estimated winds of 100 mph. A teacher reported the ground covered with hail, some golf ball-size. A weather spotter at 75th Avenue and Camelback Road reported 1.25 hail. A mile long stretch of power poles were downed near 107th Avenue and Interstate 10. Damage to the school was estimated in excess of $500,000. Total estimated damages were 9 injuries and $500,000 property damage (NCDC Storm Event Database).

- August 11, 1995, a series of strong thunderstorms moving through Tucson brought widespread damage. Many power poles were knocked over with roofs torn off some buildings. As much as four inches of rain accompanied these storms. Some areas received three-quarters inch hail. Washes in the area were running near bank full. One woman attempting to drive through a wash was swept to her fatality. Damage was estimated at $5.0 million (NCDC Storm Event Database).
- Every town in the north and western half of the Phoenix Metropolitan Area reported some damage due to a severe thunderstorm and microburst on August 14, 1996. Severe thunderstorms moved from Crown King rapidly southwestward across the west valley, producing widespread damaging winds and very heavy rainfall. The hardest hit areas were in northwest Phoenix, Glendale, and Peoria. Other towns that sustained damage were Sun City, Surprise, El Mirage, Tolleson, Avondale, Goodyear, and Buckeye. Approximately 400 power poles were knocked down throughout these towns, 100 owned by SRP and 300 owned by APS. An Arizona record wind gust of 115 miles per hour was recorded at the Deer Valley Airport. There were from 70,000 to 75,000 homeowner claims and an estimated $160 million in damage. Numerous minor injuries were also recorded (NCDC Storm Event Database, National Weather Service - Phoenix).
- March 13, 1999, very strong pre-frontal southerly winds wrecked havoc across northern Arizona. Early in the event, 90 mph (78kt) winds were measured at the Meteor Crater. Other peak wind gusts include 93 mph (81 kt) at the Winslow Airport, 104 mph (90kt) at the St. Johns Airport, and 60 mph (52 kt) at the Petrified Forest. The long duration of very strong winds induced large areas of blowing dust across the east central sections of the state. Interstate 40 westbound between Winslow and Holbrook and eastbound from Flagstaff to Holbrook was closed for eleven hours due to the cleanup of several car accidents and blown over semi trailers. During the height of the event, visibilities were down to zero on Interstate 40 in the vicinity of Winslow, with one traffic fatality occurring in a ten car pile up. A second fatality occurred 5 miles south of Snowflake when a passenger van was blown across the road and head on into a semi. On Navajo route 15, seventeen students were injured after their school bus went head on into a semi. Winds estimated at 100 mph had reduced visibilities to zero in the accident. There were numerous reports of power lines down and damaged roofs in Winslow, Leupp, and Joseph City. A total of 17 injuries and $2.0 million property damage were reported (NCDC Storm Event Database).
- Microburst winds struck the Desert Sands Trailer Park on September 19, 1999, destroying at least 14 homes and damaging 340 homes. Over 200,000 customers lost power after more than 40 power poles were snapped by the winds and rain. Talley Industries, on Greenfield Road received about $500,000 in damage as a large portion of the roof was removed by wind. A large truck was overturned near 80th Street and Baseline Road. Trees were uprooted in nearby Gilbert. A total of 2 injuries and $30.0 million property damage were reported (NCDC Storm Event Database).
- In October 2000, several days of severe thunderstorms, heavy rains, and flooding resulted in a Gubernatorial emergency declaration for Cochise, Maricopa, Pinal, and Santa Cruz Counties, and the Gila River Indian Community and subsequently a Presidential disaster declaration. Damages were estimated at $2 million property damage and $1 million crop damages (FEMA, January 26, 2001; NWS).
- A microburst hit parts of Scottsdale and Tempe with very strong winds and heavy rain on July 14, 2001. Many homes and businesses sustained damage, with at least 19 power poles blown down. One pole landed on a vehicle near Scottsdale and Indian Bend roads, killing the driver. About 6,000 residents

were left without power, including the nearby Radisson Resort. Winds ripped the roofs off four homes in the McCormick Ranch area, and dumped them up to two blocks away. Numerous trees were uprooted. A total of 1 fatality and $5.0 million property damage were reported (NCDC Storm Event Database).

- On July 14, 2002, two microbursts struck the Phoenix area. Winds from the first microburst heavily damaged the Arizona Public Service power sub-station at 7th Ave and Thomas. Widespread damage was reported across the greater Phoenix metropolitan area caused by the storm's high winds and heavy rainfall with up to 2 inches in 90 minutes. Utility companies reported that 22 power poles were downed, leaving at least 47,000 homes and businesses without power electricity for many hours. Homes in Scottsdale and Ahwatukee were struck by lightning and set on fire. The microburst caused an estimated $20 million damages (NCDC Storm Event Database).
- That same day, a second of microburst event struck Sky Harbor Airport at the Postal facility and the West economy parking lot. A large thunderstorm complex, with strong microburst winds estimated at 100 mph struck Sky Harbor International Airport. Southerly winds and dense blowing dust initially spread across the East valley and converged with a fast-moving thunderstorm in North Phoenix. These merging systems developed into a severe thunderstorm with winds that uprooted trees, took down power poles and damaged homes and businesses near the airport. Several hangars sustained major damage. Flying debris damaged five commercial aircraft, several private planes and hundreds of cars in the nearby parking lots. Numerous flights were diverted during the overnight hours due to the debris that was scattered on the runway. Property damage was reported at $30 million (NCDC Storm Event Database).

7.3.14.3 Probability and Magnitude

Thunderstorms occur throughout the year in Arizona, but most commonly during the monsoon season, the seasonal wind shift that brings a dramatic increase in moisture. Severe thunderstorms produce heavy rain, flash flooding, severe winds, hail, and lightning, all of which are addressed in detail elsewhere within this document. Rainfall is the most recognizable attendant feature of thunderstorms, with normal annual precipitation rates varying greatly across Arizona, from as little as 3 inches per year in Yuma to nearly 23 inches in Flagstaff (see Table 4-4) and posing a significant flash flooding hazard. Severe thunderstorms may also produce hail. Another hazardous feature of severe thunderstorms is tornadoes, which are generally rare in Arizona, but may cause damage and are most common in the summer months. Lightning is a hazard wherever and whenever thunderstorms occur, but can be particularly hazardous in those parts of the State highly susceptible to wildland fires.

One thunderstorm feature, microbursts, generate localized, straight-line winds reaching from 60 to over 80 mph. Microbursts are quite common in Arizona and cause significant damage. On rare occasions thunderstorms can develop much larger "macroburst" winds that have an affected outflow area of at least 2.5 miles wide and peak winds lasting between 5 and 20 minutes. Intense macrobursts may cause tornado-like damages (NWS Phoenix).

The probability of a severe thunderstorm occurring increases as the average duration and number of thunderstorm events increases. The National Weather Service (NWS) collects information on the number of thunder days (days with a thunder clap), number and duration of thunder events, and lightning strike density. An analysis of this data, collected for the period 1948-1977, provides an indication of the areal extent and frequency thunderstorm severity.

The duration of thunderstorms in Arizona is among the longest in the nation. An area stretching northwest from Flagstaff to the junction of the Arizona, Utah, and Nevada borders has an average annual thunderstorm duration of 110-130 minutes, as shown in Figure 7-24. The minimum average duration time for thunderstorms in Arizona is 70 minutes.

Despite the long duration time, the highest number of thunderstorms on average in Arizona is 70-80 annually, again concentrated north of Flagstaff to the Arizona-Utah border, as shown in Figure 7-25. This is significantly lower than in the Southeastern US, but is largely due to the concentration of most thunderstorms in Arizona during the summer monsoon season.

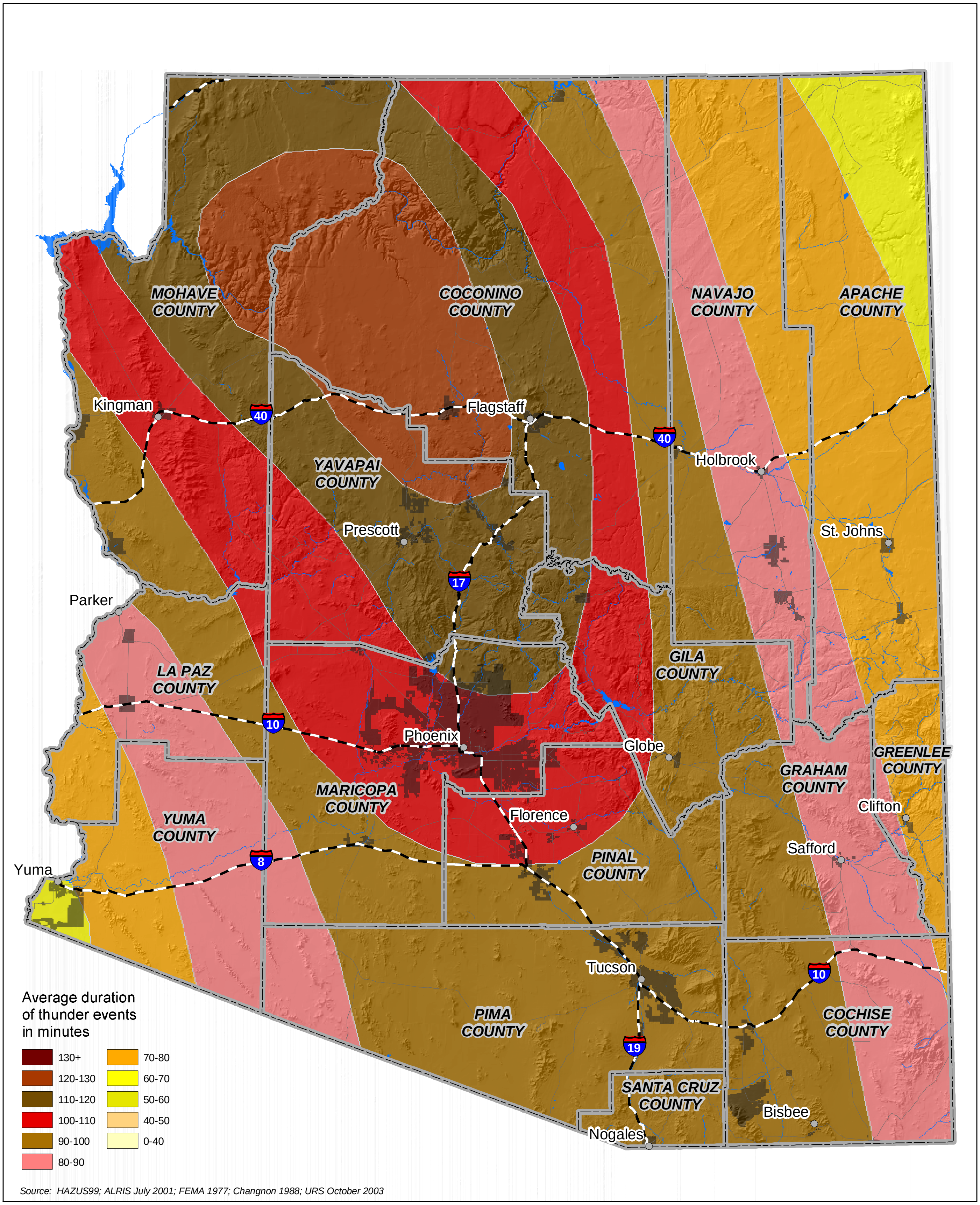
Lightning strikes are another indicator of thunderstorm hazard. Two concentrations of lightning strikes are apparent in Figure 7-26, one again in northern Arizona and another in southeastern Arizona which, respectively, have 14-16 and 12-14 lightning strikes per square kilometer annually.

7.3.14.4 Warning Time

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

Unfortunately, there is no universal answer for every severe weather event. Warning times vary based on storm location, direction, intensity, and duration. Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. However, forecasters can't issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far ahead. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona originate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

The NWS issues a severe thunderstorm watch when conditions are favorable for the development of severe thunderstorms. The local NWS office considers a thunderstorm severe if it produces hail at least 3/4-inch in diameter, wind of 58 mph or higher, or tornadoes. When a watch is issued for a region, residents are encouraged to continue normal activities but should remain alert for signs of approaching storms, and continue to listen for weather forecasts and statements from the local NWS office. When a severe thunderstorm has been detected by weather radar or one has been reported by trained storm spotters, the local NWS office will issue a severe thunderstorm warning. A severe thunderstorm warning is an urgent message to the affected counties that a severe thunderstorm is imminent. The warning time provided by a severe thunderstorm watch may be on the order of hours, while a severe thunderstorm warning typically provides warning time in the range of an hour or less.



LEGEND

Interstate — Highway
City — Major Stream
County — Lake
County Seat

0 25 50
Miles

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December 2003

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-24

Thunderstorm Hazard Severity in Arizona Based on Average Duration, 1949-1977

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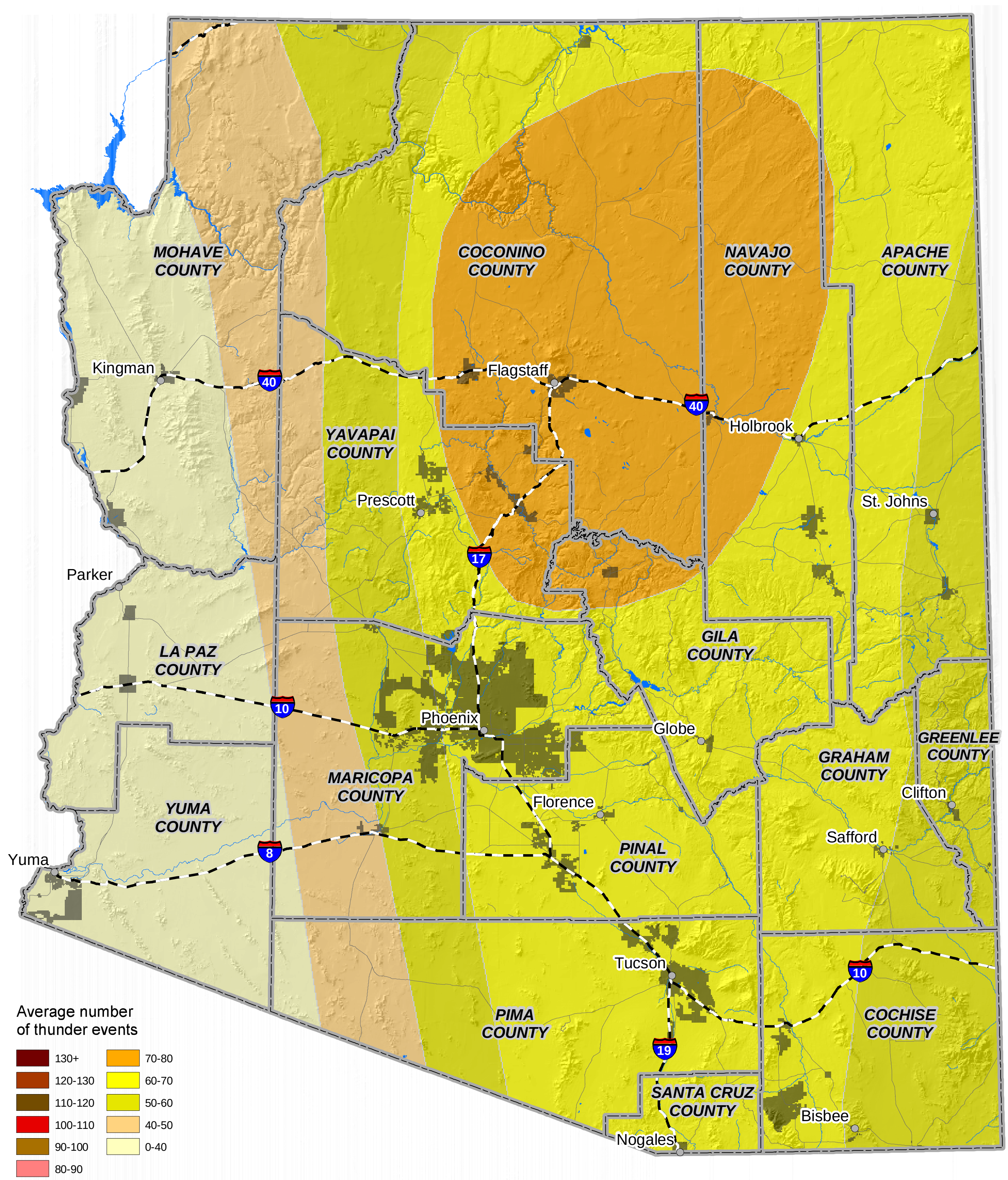

Source: HAZUS99; ALRIS July 2001; FEMA 1997; Changnon 1988; URS October 2003

LEGEND

Interstate	Highway
City	Major Stream
County	Lake
County Seat	

0 25 50
Miles

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-25
Thunderstorm Hazard Severity in Arizona Based on Average Number of Thunder Events, 1949-1977

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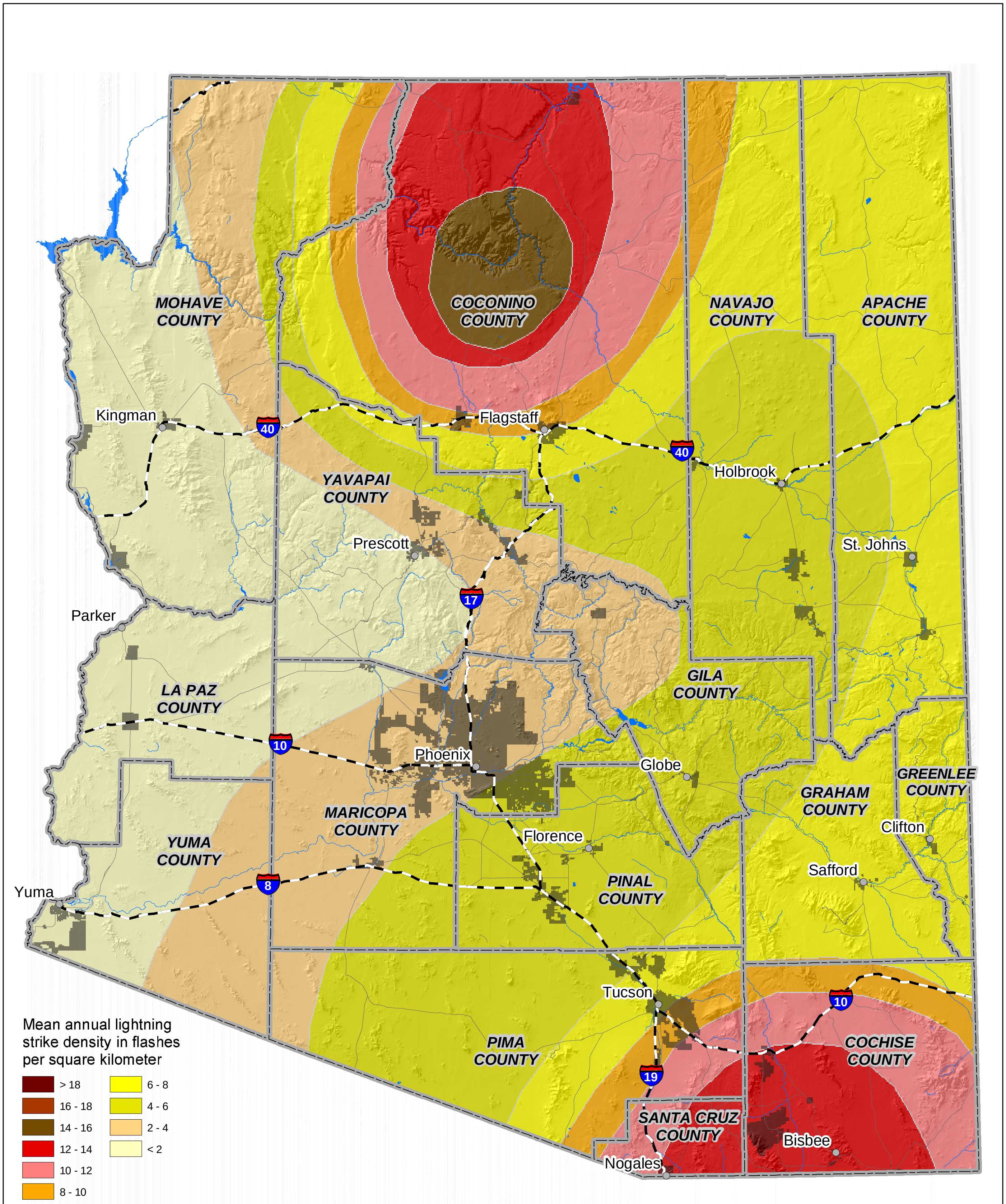
ARIZONA EMERGENCY MANAGEMENT

December 2003



Source: HAZUS99; ALRIS July 2001; FEMA 1997; Changnon 1988; URS October 2003

LEGEND

Interstate
Highway
City
Major Stream
County
Lake
County Seat

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0 25 50
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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-26

Thunderstorm Hazard Severity in Arizona Based on Lightning Strike Density, 1947-1977

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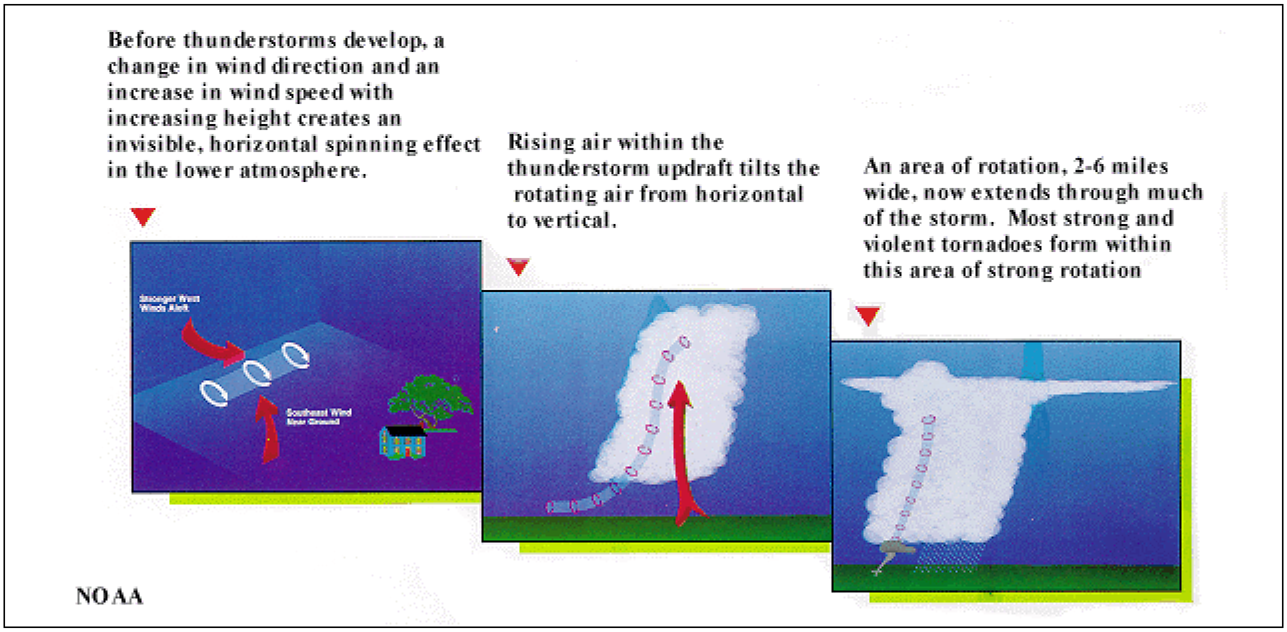
December 2003

7.3.15 Tornado

7.3.15.1 Nature

A tornado is a rapidly rotating funnel (or vortex) of air that extends toward the ground from a cumulonimbus cloud. Most tornadoes do not touch the ground, but when the lower tip of a tornado touches the earth, it can cause extensive damage. Tornadoes often form in convective cells, such as thunderstorms or at the front of hurricanes. Tornadoes may also result from earthquake induced fires, wildfires, or atomic bombs (FEMA, 1997). The formation of tornadoes from thunderstorms is explained in Figure 7-27.

Figure 7-27: How Do Tornadoes Form?



Source: NWS Phoenix.

Tornado damage severity is measured by the Fujita Tornado Scale, which assigns a numerical value of 0 to 5 based on wind speeds, as shown in Table 7-21. The letter F may precede the number (e.g., FO, F1, F2). Most tornadoes last less than 30 minutes, but some last for over an hour. The path of a tornado can range from a few hundred feet to miles. The width of a tornado may range from tens of yards to more than a quarter of a mile.

Table 7-21: Fujita Tornado Scale		
Category	Wind Speed	Description of Damage
F0	40-72 mph	Light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards.
F1	73-112 mph	Moderate damage. The lower limit is the beginning of hurricane speed. Roof surfaces peeled off; mobile homes pushed off foundations or overturned; moving autos pushed off roads.
F2	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	158-206 mph	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; cars lifted off ground and thrown.
F4	207-260 mph	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	261-318 mph	Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100-yards; trees debarked.

Source: FEMA, 1997.

7.3.15.2 History

In an average year, 800-1200 tornadoes are reported nationwide, resulting in approximately 80 deaths and 1,500 injuries. Nearly 75 percent of tornado damage is relatively minor, with the associated tornadoes rated F0 or F1. However, some tornadoes are some are capable of tremendous destruction, particularly to densely populated areas (NWS Flagstaff, McCarthy 2003).

A total of 40 significant tornadoes affecting Arizona were identified, as shown in Table 7-3, none of which resulted in a disaster/emergency declaration. These events caused at least one injury, one death, $50,000 worth of damage, or were severe enough to be identified in historical records. Most of the significant tornado events were identified using the National Climate Center (NCDC) Storm Event Database, which has a large number of well-recorded events from approximately 1970 forward. A total of four fatalities were recorded, 185 injuries, and $42.9 million in damages. These events include the following:

- On August 4, 1957, an F3 tornado was identified in Maricopa County, with no reported injuries or damages (NCDC Storm Event Database).
- On August 27, 1964, an F2 tornado in Pima County caused 2 fatalities and 9 injuries (NCDC Storm Event Database).
- On August 30, 1970, an F2 tornado in Maricopa County caused 41 injuries (NCDC Storm Event Database).
- On June 21, 1972, an F2 tornado in Pinal County caused 3 injuries and $25 million in damages (NCDC Storm Event Database).
- On August 10, 1972 an F3 tornado was identified in Yavapai County, with no injuries or damages recorded (NCDC Storm Event Database).

- On June 23, 1974, one person was killed and 40 injured by an F2 tornado in Pima County (NCDC Storm Event Database).

- In September of 1996 an F1 tornado moved through Chino Valley in Northern Arizona. Two mobile homes received moderate damage and were moved off their foundations. Several power poles were snapped off at three feet above the ground and a greenhouse was extensively damaged. The tornado caused $250,000 in property damage and $30,000 in crop damage (NCDC Storm Event Database).

7.3.15.3 Probability and Magnitude

Most Arizona tornadoes occur from July through September, with nearly all category F0 and F1 on the Fujita scale and only two F3 tornadoes reported in Arizona since 1950. Compared to Oklahoma which receives on average 7.5 tornadoes annually, the highest state rate of occurrence per 10,000 state square miles, tornadoes are rare in Arizona, occurring at a rate of 0.3 annually per 10,000 state square miles.

Based on data from 1950-1995 analyzed by the Disaster Center, Arizona annually has an average of three tornadoes, less than one fatality, three injuries, and $1.3 million in damages. Arizona ranks number 34 in comparison with other states for frequency of tornadoes, 31 for number of deaths, 32 for injuries and 32 for cost of damages. When compared to other states in terms of square miles, Arizona ranks number 45 for frequency of tornadoes, number 35 for fatalities per square mile, number 38 for injuries per square mile, and number 39 for costs per square mile (Disaster Center).

7.3.15.4 Warning Time

Arizona has three National Weather Service (NWS) forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories).

The NWS issues a tornado watch to give advanced notice that tornadoes are possible in an area. This gives people time to make preliminary plans for moving to a safe location if a tornado warning is issued. A tornado warning is an urgent announcement that a tornado has been reported or is imminent and warns people to take immediate cover. The warning time provided by a tornado watch may be on the order of hours, while a tornado warning typically provides warning time in the range of tens of minutes.

Before severe weather watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. Forecasters can't issue alerts for the danger of severe thunderstorms, tornadoes and flash floods that far ahead. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona emanate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

7.3.16 Tropical Cyclone

7.3.16.1 Nature

A tropical cyclone is a low-pressure area of closed circulation winds that originates over tropical waters, with winds that rotate counterclockwise in the Northern Hemisphere. Tropical cyclones may range from 100 to 500 miles in diameter, with the storm rotating around an area of low barometric pressure, known as the eye, which may be 10 to 30 miles in diameter. Tropical cyclones cause damage through a variety of associated phenomena, including severe winds, storm surge flooding, high waves, coastal erosion, extreme rainfall, thunderstorms, lightning, and tornadoes (most of these are addresses more fully elsewhere in this document). Hurricanes are among the most destructive forces on the planet and are the focus of significant monitoring and mitigation efforts. Because tropical cyclones, themselves, cannot make landfall in Arizona and rarely retain the qualities of an organized tropical system by the time they reach Arizona, mitigation planning that is associated with this phenomena is focused on accompanying hazards such as extreme rainfall, flooding, high wind, and lightning.

Tropical cyclones start as a tropical depression, with winds speeds below 39 mph, that may intensify into a tropical storm and may go on to become a hurricane or typhoon. Eventually the storm weakens as it travels over land or colder waters. The classification criteria for tropical storms are shown in Table 7-22. Hurricanes are further classified based on the Safir/Simpson scale, as shown in Table 7-23.

Table 7-22: Classification Criteria for Tropical, Subtropical and Extratropical Cyclones

Development Stage	Criteria
Tropical Depression (development)	The formative stages of a tropical cyclone in which the maximum sustained (1-min mean) surface wind speed is <39 mph (<18 m/s).
Tropical Storm	A warm core tropical cyclone in which the maximum sustained surface wind speed (1-min mean) ranges from 39 to <74 mph (18 to <33 m/s).
Hurricane	A warm core tropical cyclone in which the maximum sustained surface wind speed (1-min mean) is at least 74 mph (33 m/s).
Tropical Depression (dissipation)	The decaying stages of a tropical cyclone in which the maximum sustained surface wind speed (1-min mean) has dropped below 39 mph (18 m/s).
Extratropical Cyclone	Tropical cyclones modified by interaction with nontropical environment. There are no wind speed criteria, and maximum winds may exceed hurricane force.
Subtropical Depression	A subtropical cyclone in which the maximum sustained surface wind speed (1-min mean) is below 39 mph (18 m/s).
Subtropical Storm	A subtropical cyclone in which the maximum sustained surface wind speed (1-min mean) is at least 39 mph (18 m/s).

Source: FEMA, 1997; modified from Neumann and others, 1993.

Table 7-23: Saffir/Simpson Hurricane Scale Ranges					
Scale Number (Category)	Central Pressure (mbar)	Central Pressure (inches)	Wind Speed (mph)	Storm Surge (feet)	Potential Damage
1	980+	28.94+	74 – 95	4 – 5	Minimal
2	965 – 979	28.50 – 28.91	96 – 110	6 – 8	Moderate
3	945 – 964	27.91 – 28.47	111 – 130	9 – 12	Extensive
4	920 – 944	27.17 – 27.88	131 – 155	13 – 18	Extreme
5	<920	<27.17	>155	>18	Catastrophic

Source: FEMA, 1997; Herbert and others, 1995.

7.3.16.2 History

Tropical cyclones approaching the western U.S. from the Pacific Ocean tend to weaken quickly, but their remnants are capable of delivering large amounts of rainfall to California, Nevada, Arizona, and New Mexico. The remnants of tropical cyclones affect Arizona infrequently, but are responsible for some of the most intense rainfall and flooding events in Arizona. Sometimes moisture associated with eastern Pacific hurricanes and tropical storms gets pulled north by the monsoon flow. When this occurs, continuous heavy rains can persist for 24 to 48 hours or longer, causing serious flooding.

A total of 13 tropical cyclones Arizona were identified, as shown in Table 7-3, four of which resulted in a disaster/emergency declaration. A total of 38 fatalities were recorded, 975 injuries, and $750.8 million in damages, most of which were due to flooding associated with the tropical cyclones. These events include the following:

- In October 1962, the remains of Tropical Storm Claudia caused sever flash flooding in and around Tucson. Up to seven inches of rain fell in the desert just west of Tucson near the Arizona Desert Museum. Flood waters inundated Marana and Sells (ADEM, December 2001).

- In September 1970, the remains of tropical storm Norma brought severe flooding to Arizona and became the deadliest storm in Arizona history, leading to a Presidential disaster declaration. There were 23 fatalities in central Arizona, including 14 from flash flooding in Tonto Creek in the vicinity of Kohl's ranch. The total rainfall at Workman Creek about 30 miles north of Globe in the Sierra Ancha mountains was 11.92 inches, with 11.40 inches in 24 hours. This remained the 24 hour rainfall record rainfall for Arizona until 1997. Other rainfall amounts included 9.09 at Upper Parker Creek, 8.74 inches at Mount Lemmon, 8.44 inches at Sunflower, 8.08 at Kitt Peak, 7.12 at the Tonto Creek fish hatchery, and 7.01 inches at Crown King (ADEM, December 2001).

- In October 1972, the remains of Hurricane Joanne brought heavy rain and flooding to much of the state. It was the first documentation of a tropical storm reaching Arizona with the cyclonic circulation intact. Severe flooding occurred in the Clifton, Duncan and Safford areas (ADEM, December 2001).

- In September 1976, the remains of Hurricane Kathleen moved across Baja and into southern California near El Centro. With its circulation still intact a tropical storm force winds produced considerable damage in Yuma. Sustained winds exceeded 50 mph and gusts as high as 76 mph. One man was killed when a 75-foot palm tree crashed into his mobile home. Severe flooding occurs in Mohave County and across southern California. Residual moisture brought more severe thunderstorms to the state on September 24 and 25. The Tucson area was particularly hard hit with flash flooding and hail as large as golf balls. Hail covered the ground to a depth of 5 inches on Mount Lemon (ADEM, December 2001).

- In October 1977, the remains of Hurricane Heather produced heavy rain and major flooding over extreme southern Arizona.8.3 inches of rain fell at Nogales, with as much as 14 inches in the surrounding mountains (ADEM, December 2001).

- In late September 1983, Arizona was struck by a particularly strong tropical low. Flooding killed eight persons, reportedly injured 975, and caused $226.5 million in damages in the State. (FEMA, January 1991).

- In September 1997, Tropical Storm Nora reached the level of a category four hurricane before making landfall in California. Nora caused enormous flooding and $375 million in damages in Arizona, leading to a Presidential disaster declaration. The calculated 24-hour, 100-year rainfall amount in NW Maricopa County was exceeded at six Automated Local Evaluation in Real Time (ALERT) measuring sites. Yuma observed a 2-minute sustained wind of 45 mph during Nora's passage, a rarity in the United States for eastern Pacific tropical cyclones. Peak gusts of 54 mph, and 52 mph were also observed (ADEM, December 2001; NCDC, Storm Event Database; Maricopa County Flood Control District, September 2003; NWS).

- In October 2000, Tropical Storm Olivia remnants of Tropical Storm Olivia brought 3 to 5 inches of rain to southeastern Arizona, leading to a Gubernatorial emergency declaration for Santa Cruz County (ADEM, December 2001).

7.3.16.3 Probability and Magnitude

Tropical cyclone probability is generally derived from coastal flooding caused by storm surge or by the frequency of tropical cyclones is determined by the number of landfall events over a given period of time for specific geographic areas. Since Arizona is not a coastal state and, in comparison with most coastal states, it has experienced few tropical cyclones, the probability and magnitude of tropical cyclone events has not been estimated for Arizona. However, as indicated by the historic data above, Arizona was affected by eight identified tropical cyclone events during the years 1962-2000, several of which caused massive damage, primarily via flooding. This suggests a low probability, but potentially high magnitude for tropical cyclones in Arizona.

7.3.16.4 Warning Time

Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona emanate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

A part of the NWS, the Tropical Prediction Center (TPC) issues watches, warnings, forecasts, and analyses of hazardous weather conditions in the tropics. The National Hurricane Center (NHC), a part of the TPC, maintains a continuous watch on tropical cyclones over the Atlantic, Caribbean, Gulf of Mexico, and the Eastern Pacific from 15 May through November 30. A hurricane watch indicates the possibility that hurricane conditions are expected within 36 hours. A watch should trigger disaster plans and protective measures, especially those actions that require extra time such as securing a boat, leaving a barrier island, etc. A hurricane warning indicates that sustained winds of at least 74 mph are expected within 24 hours or less. Once a warning has been issued, protective actions should be complete and movement to the safest location during the storm underway.

Arizona has three NWS forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories). The warning time provided by a hurricane watch is on the order of days, while a hurricane warning typically provides warning time of 24 hours. This time should be sufficient for people to move to safety, although damage from a hurricane may still be significant. Given the historically small impact hurricane systems have had on Arizona an elaborate system to effectively provide advance notice for hurricane events may not be necessary. Instead, advance-warning techniques are most appropriate for specific hazards that are associated with the hurricane system, including flash floods, high winds, and lightning.

Unfortunately, there is no universal answer for every rainfall event. Warning times vary based on storm location, direction, intensity, duration, and the topography and size of the drainage area.

7.3.17 Wildfire

7.3.17.1 Nature

A wildfire is an uncontrolled fire spreading through vegetative fuels, exposing and possibly consuming structures. They often begin unnoticed, spread quickly, and are usually signaled by dense smoke that may fill the area for miles around. Wildfires can be human-caused through acts such as arson or campfires, or can be caused by natural events such as lightning. Wildfires can be categorized into four types:

- **Wildland fires** occur mainly in areas under federal control, such as national forests and parks, and are fueled primarily by natural vegetation.
- **Interface or intermix fires** occur in areas where both vegetation and structures provide fuel. These are also referred to as urban-wildland interface fires.
- **Firestorms** occur during extreme weather (e.g., high temperatures, low humidity, and high winds) with such intensity that fire suppression is virtually impossible. These events typically burn until the conditions change or the fuel is exhausted.
- **Prescribed fires and prescribed natural fires** are intentionally set or natural fires that are allowed to burn for beneficial purposes.

The following three factors contribute significantly to wildfire behavior and, as detailed more fully later, they can be used to identify wildfire hazard areas:

- **Topography**: As slope increases, that is the divergence of the terrain from horizontal, the rate of wildfire spread increases. South facing slopes are also subject to greater solar radiation, making them drier and thereby intensifying wildfire behavior. However, ridgetops may mark the end of wildfire spread, since fire spreads more slowly or may even be unable to spread downhill.
- **Fuel**: Weight or volume are the two methods of classifying fuel, with volume also referred to as fuel loading (measured in tons of vegetative material per acre). Each fuel is assigned a burn index (the estimated amount of potential energy released during a fire), an estimate of the effort required to contain a wildfire, and an expected flame length. The fuel's continuity is also an important factor, both horizontally and vertically.
- **Weather**: The most variable factor affecting wildfire behavior is weather. Important weather variables are temperature, humidity, wind, and lightning. Weather events ranging in scale from localized thunderstorms to large fronts can have major effects on wildfire occurrence and behavior. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildfire activity. By contrast, cooling and higher humidity often signals reduced wildfire occurrence and easier containment.

The frequency and severity of wildfires is also dependent upon other hazards, such as lightning, drought, and infestations (e.g., Pine Bark Beetle). In Arizona, these hazards combine with the three other wildfire contributors noted above (topography, fuel, weather) to present an on-going and significant hazard across much of Arizona.

If not promptly controlled, wildfires may grow into an emergency or disaster. Even small fires can threaten lives, resources, and destroy improved properties. It is also important to note that in addition to affecting people, wildfires may severely affect livestock and pets. Such events may require the emergency watering/feeding, shelter, evacuation, and event burying of animals.

The indirect effects of wildfires can also be catastrophic. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways and the land itself. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams thereby enhancing flood potential, harming aquatic life and degrading water quality. Lands stripped of vegetation are also subject to increased landslide hazards.

7.3.17.2 History

Wildfires burn thousands of acres in Arizona annually, as shown in Table 7-24. During the period 1992-2002, Arizona had an average of 3,737 fires annually, affecting an average of 163,407 acres. On average, 58 percent of the wildfires were human caused, while 42 percent were lightning caused.

Table 7-24: Wildfires in Arizona by Type, 1992-2002

	Human Caused		Lightning Caused		Total	
Year	**Fires**	**Acres Burned**	**Fires**	**Acres Burned**	**Fires**	**Acres Burned**
1992	2,353	33,770	1,603	7,836	3,956	41,606
1993	3,719	117,049	1,016	87,725	4,735	204,774
1994	2,469	40,793	2,110	182,106	4,579	222,899
1995	3,318	119,366	1,526	125,397	4,844	244,763
1996	1,747	89,916	2,033	98,271	3,780	188,187
1997	1,500	8,962	1,302	9,585	2,802	18,547
1998	2,317	43,432	916	7,718	3,233	51,150
1999	1,416	50,605	1,795	31,675	3,211	82,280
2000	1,407	45,657	2,172	37,239	3,579	82,896
2001	1,820	12,762	1,347	17,741	3,167	30,503
2002	1,833	599,383	1,385	30,493	3,218	629,876
Average	2,173	105,609	1,564	57,799	3,737	163,407

Source: US Forest Service, 2003.

Information on the location and size of wildfire events in Arizona were collected from a variety of sources. However, most of the information came from the following two sources:

- The USDA Forest Service has published a study titled *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management* (April 2002). This study describes and makes available seven coarse-scale (1 square kilometer) resolution spatial data layers for the conterminous U.S. to support national-level fire planning and risk assessments. One of the layers, National Fire Occurrence, 1986 to 1996, contains information on Federal and non-Federal wildfire occurrence, including date, location, area burned, and cause. Information for wildfires in Arizona was retrieved from this layer. These events were screened to include only fires 100+ acres in size.

- The Arizona State Land Department's wildfire dispatcher working database of wildfire incidents in Arizona from 1994 to 2002 (Pearlberg, April 3, 2003). This database included information on the date, location, area burned, and cause of wildfires. In order to avoid overlap, information from this database was used for the period 1997 to 2002. These events were screened to include only fires 100+ acres in size

A total of 702 significant wildfires in Arizona were identified during the period 1968-2002, as shown in Table 7-24, which is the highest number of hazard events identified in Arizona across all hazard categories. These events were at least 100 acres in size or were severe enough to be identified in historical records. A total of six fatalities, no injuries, and $34.3 million in damages were identified for all wildfires. A disaster/emergency declaration made for 27 wildfires. The following are some of the largest wildfires in Arizona's history:

- In 1971, several lightning strikes ignited the Carrizo Fire, which consumed 57,335 acres of Apache National Forest land (Arizona Republic, June 20, 2003).

- In July 1979, lightning caused the Verde Fire, which spread over 35,678 acres of Tonto National Forest land about 40 miles northeast of Phoenix. Also, the Castle Fire, was caused by a lightning strike about 50 miles northwest of Phoenix in the Bradshaw Mountains, with the fire burning 28,600 acres in the Prescott National Forest (Arizona Republic, June 20, 2003).

- On June 25, 1990, the Dude Fire killed six firefighters, destroyed 63 homes, and burned 24,174 acres in the Tonto National Forest, northeast of Payson (Arizona Republic, June 30, 2003).

- In 1994, the Rattlesnake Fire was started by lightning and burned 27,500 acres in the Chiricahua Mountains northeast of Douglas (Arizona Republic, June 30, 2003).

- Also in 1994, the Perkins Fire burned 25,946 acres of Bureau of Land Management land near Phoenix (Arizona Republic, June 30, 2003).

- On April 27, 1996, the Lone Fire was started by campers in the Tonto National Forest near Roosevelt Lake and eventually burned 61,370 acres of canyons and scrub-covered mountains (Arizona Republic, June 20, 2003).

- In June 1996, the Bridger Knoll Fire started with lightning below the North Rim of the Grand Canyon in the Kaibab National Forest. High winds whipped it out of the Canyon and onto forest land, burning53,503 acres before it was contained (Arizona Republic, June 20, 2003).

- In April 2002, the Ryan Fire burned 38,124 acres in the Canelo Hills area, about 70 miles southeast of Tucson (Arizona Republic, June 20, 2003).

- The largest fire in Arizona history was started on June 18, 2002, when an arsonist set the Rodeo Fire on the Fort Apache Indian Reservation near the Rodeo Fairgrounds. On June 20, a second blaze began near Chediski Peak, 15 miles from the Rodeo fire. The two fires spread quickly northeast and steadily widened toward each other, combining on June 23. On June 25, President Bush declared a national disaster for Apache, Coconino, Gila, Navajo Counties, and the Fort Apache Reservation. The fire continued to burn uncontrolled until contained on July 7, by which time it had burned over 468,638 acres in Navajo, Gila, and Coconino Counties. The fire caused 30,000 people to evacuate, destroyed over 450 homes, and caused an estimated $34 million in damages. An estimated $50 million dollars were spent fighting the fire. Fifty-eight percent of the burned area experienced high intensity burn. Extensive smoke damage occurred in Apache County outside the direct burn area. Further, the critical Little Colorado River, and Salt River watersheds are subject to increased erosion and siltation for years to come (FEMA, September 2002).

The location of significant wildfires (100+ acres) in Arizona is shown in Figure 7-28, with the number of wildfires per county tabulated in Table 7-25. A strong concentration in the southeastern quarter of Arizona is apparent, with particularly high wildfire incident counts for Cochise, Pima, and Maricopa Counties. Numerous wildfire counts are also apparent across the central and north-central portion of the state. As illustrated through Figure 7-28, many of the wildfires Arizona has endured over the past 34 years have occurred near the State's primary population centers. Arizona, with a localized resident base that continues to expand at a significant rate, is projected to experience a growing number of wildfire events that affect this growing population. This may occur because many of Arizona's new residents may choose to live in areas that have been relatively protected from loss caused by wildfire events. This has been the circumstance because Arizona's historically small population has not necessitated the development of infrastructure needed to facilitate new construction in forested and other non-urban areas. If current development trends in Arizona's larger communities continue, however, this circumstance may change. In particular, with the burgeoning metropolitan regions of Phoenix and Tucson located near vulnerable natural features, this threat is expected to become more and more pervasive.

Table 7-25: Significant Wildfires in Arizona by County, 1968-2002

	Wildfire Size			
County	**100-499 acres**	**500-999 acres**	**1,000+ acres**	**Total**
Apache	7	3	1	11
Cochise	95	29	21	145
Coconino	16	2	5	23
Gila	7	1	2	10
Graham	11	3	4	18
Greenlee	1	0	3	4
La Paz	8	3	0	11
Maricopa	42	7	12	61
Mohave	26	16	10	52
Navajo	4	0	0	4
Pima	51	7	19	77
Pinal	87	9	17	113
Santa Cruz	14	6	5	25
Yavapai	18	5	6	29
Yuma	3	1	1	5
Total	**390**	**92**	**106**	**588**

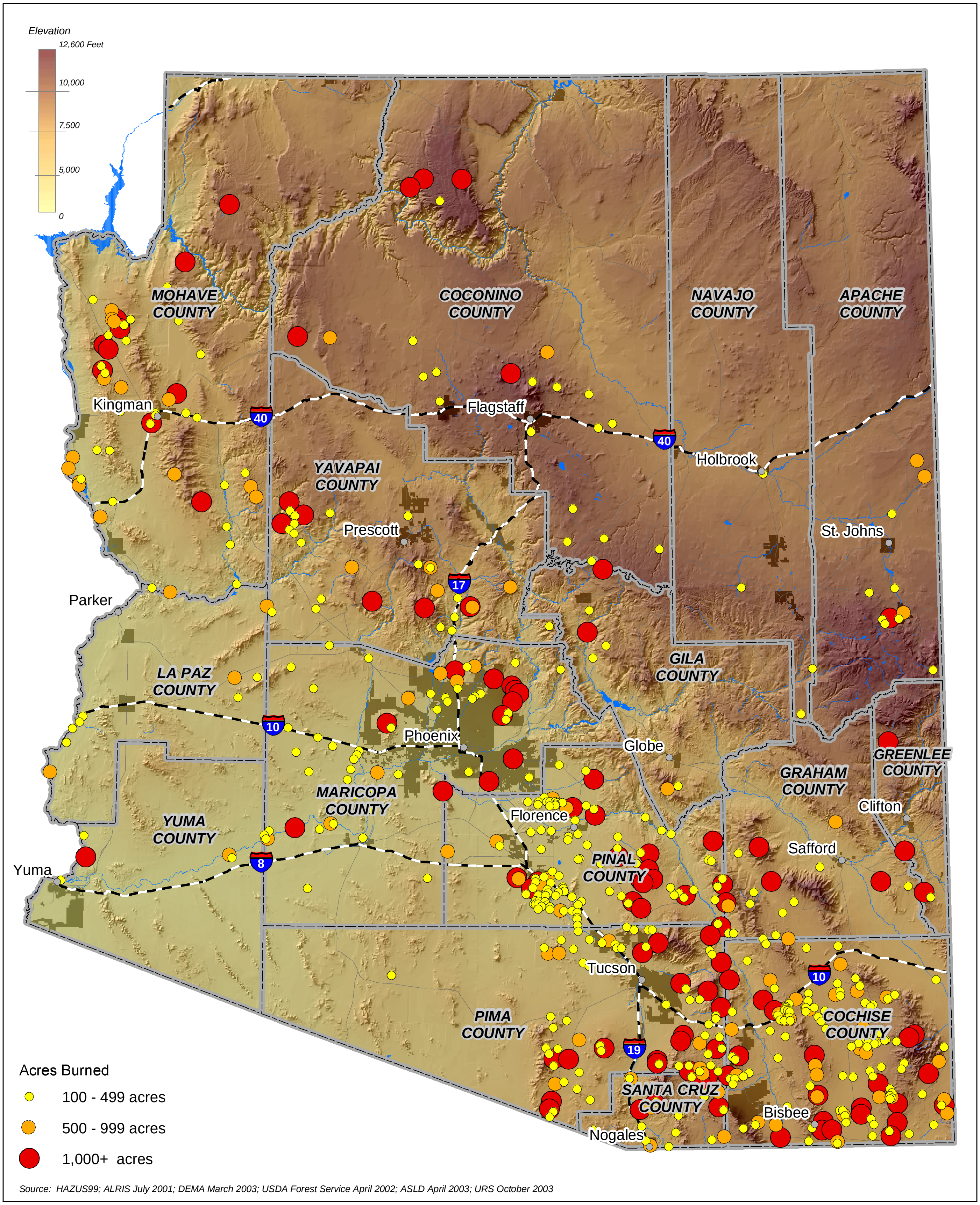
Note: Counts taken from Figure 7-28. Only those wildfires that could be accurately located (geocoded) are counted above.

Source: USDA Forest Service, April 2001; Arizona State Land Department; URS, October 2003.

7.3.17.3 Probability and Magnitude

Depending upon the needs of the user and the availability of data, there are many different approaches to fire modeling. However, nationally accepted or utilized wildfire models have not been developed for the evaluation of wildfire risk or conducting vulnerability analysis. In addition, most wildfire modeling conducted to date has been focused on wildfire behavior, not true probability and magnitude modeling. This is because the probability of ignition and the probable wildfire size have generally not been considered. In addition, there have been major limitations in terms of software systems, data availability, and data coverage/resolution.

These limitations aside, with improving Geographic Information Systems (GIS) programs and data availability, there are a growing number of wildfire hazard assessment models. In addition, as a part of the National Fire Plan, communities have also been identified across the U.S. that are at risk to wildfires. Finally, using an approach utilized by the International Fire Code Institute (IFCI), FEMA has a suggested approach to identify wildfire hazard areas. These are each addressed below, with specific information on Arizona identified where available.



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December 2003

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Figure 7-28
Significant Wildfires in Arizona, 1968-2002

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7.3.17.3.1 Wildfire Behavior Models

Most wildfire modeling efforts to date have been focused on wildfire behavior. Most of these models have been developed and are maintained under the direction of the USDA Forest Service FireLab at Missoula, Montana. Other wildfire behavior models and data sources widely used by federal and state land management agencies to wildfire behavior include the following: BEHAVE, FARSITE, FlamMap, FireFamilyPlus, and FOFEM. These models generally have the ability to simulate the behavior of wildfires for a given area with specified topographic, fuel load, and weather characteristics. Such models have not, however, generally included probability and magnitude factors, such as ignition probability, rate of spread, suppression, etc.

The most well-known of these models is BEHAVE, which was originally developed prior to widespread access to significant personal computer power, resulting in its development as a series of modules. The BEHAVE model is generally used to predict fire behavior and model fuel systems. The program has the ability to model fire behavior such as fire rate of spread and intensity, spotting distance, scorch height, etc. A recent update, BehavePlus, is a program for personal computers that is a collection of mathematical models that describe fire and the fire environment with tables, graphs, and simple diagrams. It can be used for a multitude of fire management applications including projecting the behavior of an ongoing fire, planning prescribed fire, and training. Primary modeling capabilities include surface fire spread and intensity, safety zone size, size of point source fire, fire containment, spotting distance, crown scorch height, tree mortality, and probability of ignition.

No statewide wildfire behavior model coverage was identified for Arizona.

7.3.17.3.2 Coarse-Scale Spatial Data for Wildland Fire and Fuel Management

As noted above, the USDA Forest Service has published a study titled *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management* (April 2002). This study describes and makes available seven coarse-scale (1 square kilometer) resolution spatial data layers for the conterminous U.S. to support national-level fire planning and risk assessments. Note that this study includes a limitation that the data are most useful at the national level and were not intended for use at scales other than a coarse scale.

One of the layers, *Wildland Risk to Flammable Structures (Version 1.0, December 2000)*, is a spatial layer of the potential risk of wildland fire burning flammable structures based on an integration of housing density, fuel, and weather layers:

- Housing Density is estimated using data on population from the Oak Ridge National Laboratory (ORNL) LandScan Global Population 1998 Database. This database estimates not just residential population, but also “ambient” that may be using travel infrastructure such as highways, to estimate population. Housing density was estimated based on ambient population density, where three people equal one house.

- The Potential Fire Exposure Layer classifies vegetation types into fire behavior classes that exhibit similar fire or heat intensity under extreme weather conditions. This layer was created by combining two other layers developed as a part of the project, the Potential Vegetation Groups and the Current Cover Types.

- Extreme Fire Weather Potential is a classification of the average number of days per year where weather conditions, specifically temperature, relative humidity, and wind speed, were similar to conditions under which wildland fires had burned multiple structures in a single event. Flammable structures are structures that have a low resistance to ignition. Wildland fires are vegetation fires that start and burn in unpopulated/undeveloped areas. This layer was developed using data from the International Surface Weather Observations, 1982-1997 from the U.S. Air Force Combat Climatology Center and the National Climatic Data Center.

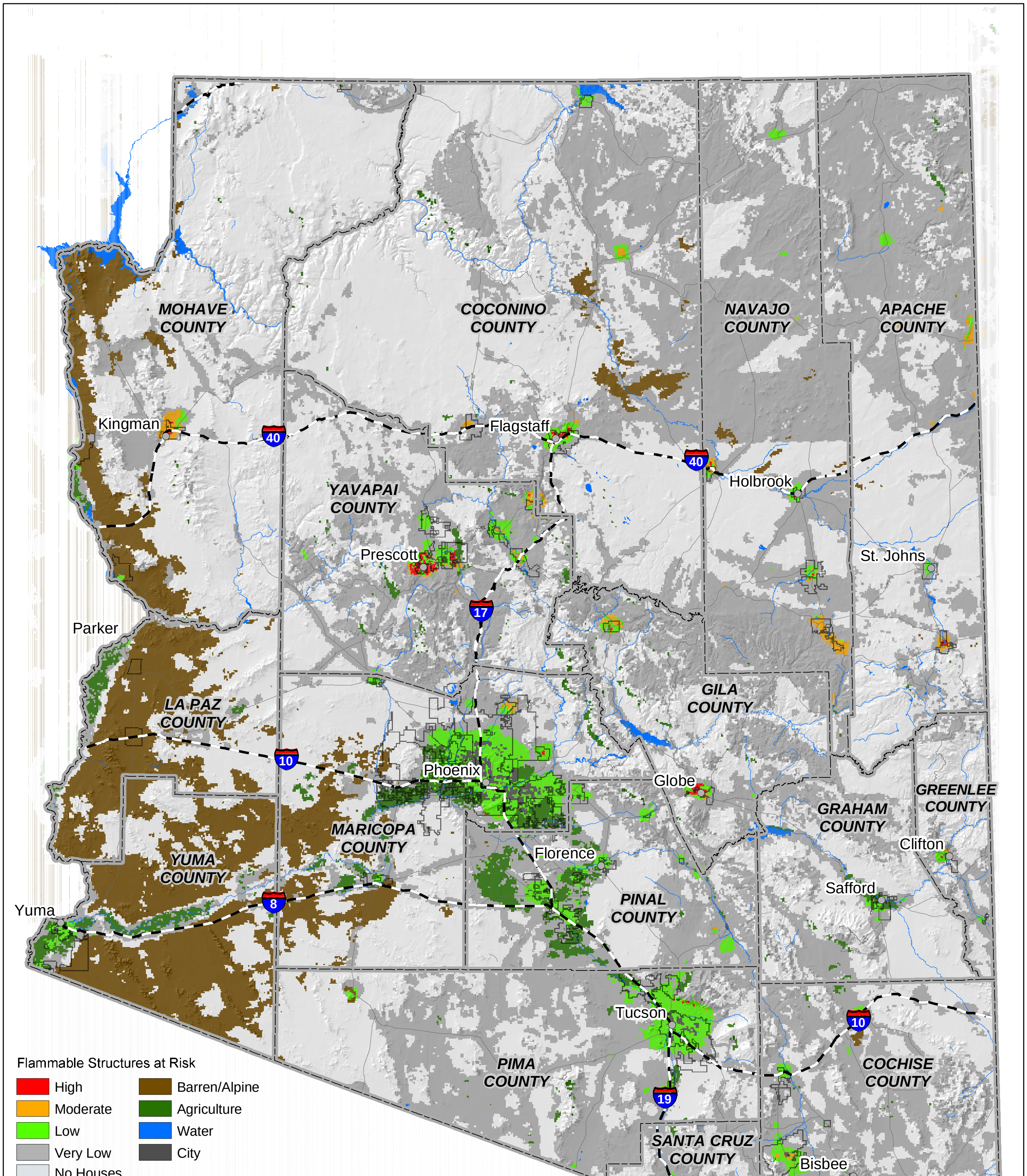
Based on this analysis, most of Arizona is classified under the model as “No houses,” “Barren” or “Very Low Risk,” as shown in Figure 7-29. The risk rises to “Low” in the vicinity of Phoenix, Tucson, Flagstaff, and Prescott. “Moderate” risk is identified in the vicinities of some smaller communities scattered around the state. No large areas of high risk are identified.

7.3.17.3.3 Wildland Urban Interface Communities at Risk Program

The urban wildland interface is an area in which development meets wildland vegetation, where both vegetation and the built environment provide fuel for fires. Urban wildland interface areas have increased significantly throughout the U.S. and now face the risk of major losses from wildfires. Following the severe wildfires during the summer of 2000, the Secretaries of Agriculture and the Interior developed the National Fire Plan, a program to reduce wildland fire risks to communities and the environment, and also to save the lives of firefighters and the public. The Plan is a long-term program based on cooperation and communication among federal agencies, states, local governments, tribes and interested publics. The program includes a 10-Year Comprehensive Strategy and an Implementation Plan.

As part of the National Fire Plan, the Wildland Urban Interface Communities at Risk Program was developed in order to reduce the risk of wildland fire in urban interface communities through education, prevention, hazardous fuels reduction, and to increase fire protection capabilities. A key step in realizing this goal was the identification of areas that are at high risk of damage from wildfire. Federal fire managers authorized state and tribal authorities to determine which communities were under significant risk from wildland fire on or in the vicinity of Federal lands. In some states, communities that are not on or within the vicinity of wildfires were also included, primarily in eastern states. States and tribes were asked to follow a consistent process established by an interagency group at the national level, or state teams could use existing community assessment systems when those systems met or exceeded the standardized process. The outcome of this process was the *Wildland Urban Interface Communities at Risk*, which was first published in the Federal Register on January 4, 2001 and revised to include additional communities on August 17, 2001.

The information contained in the revised list is used by interagency groups of land managers at the state and/or tribal level to collaboratively identify priority areas benefiting from hazardous fuels reduction. Federal land management agencies and state foresters will focus special attention on these areas in a concerted effort to reduce wildfire hazards. In Arizona, 122 communities were identified, as shown in Table 7-26 and Figure 7-30. Significant concentrations of these communities are apparent in Gila, Coconino, Navajo, Yavapai, and Apache Counties.



Note: Note that this study includes a limitation that the data were developed at a 1 square kilometer resolution, making then most useful at the national level, and were not intended for use at scales other than a coarse scale.

Source: HAZUS99; ALRIS July 2001;USDA Forest Service April 2002; URS October 2003

LEGEND

- Interstate
- Highway
- City
- Major Stream
- County
- Lake
- County Seat

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State of Arizona
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Figure 7-29
Wildland Fire Risk to Flammable Structures in Arizona

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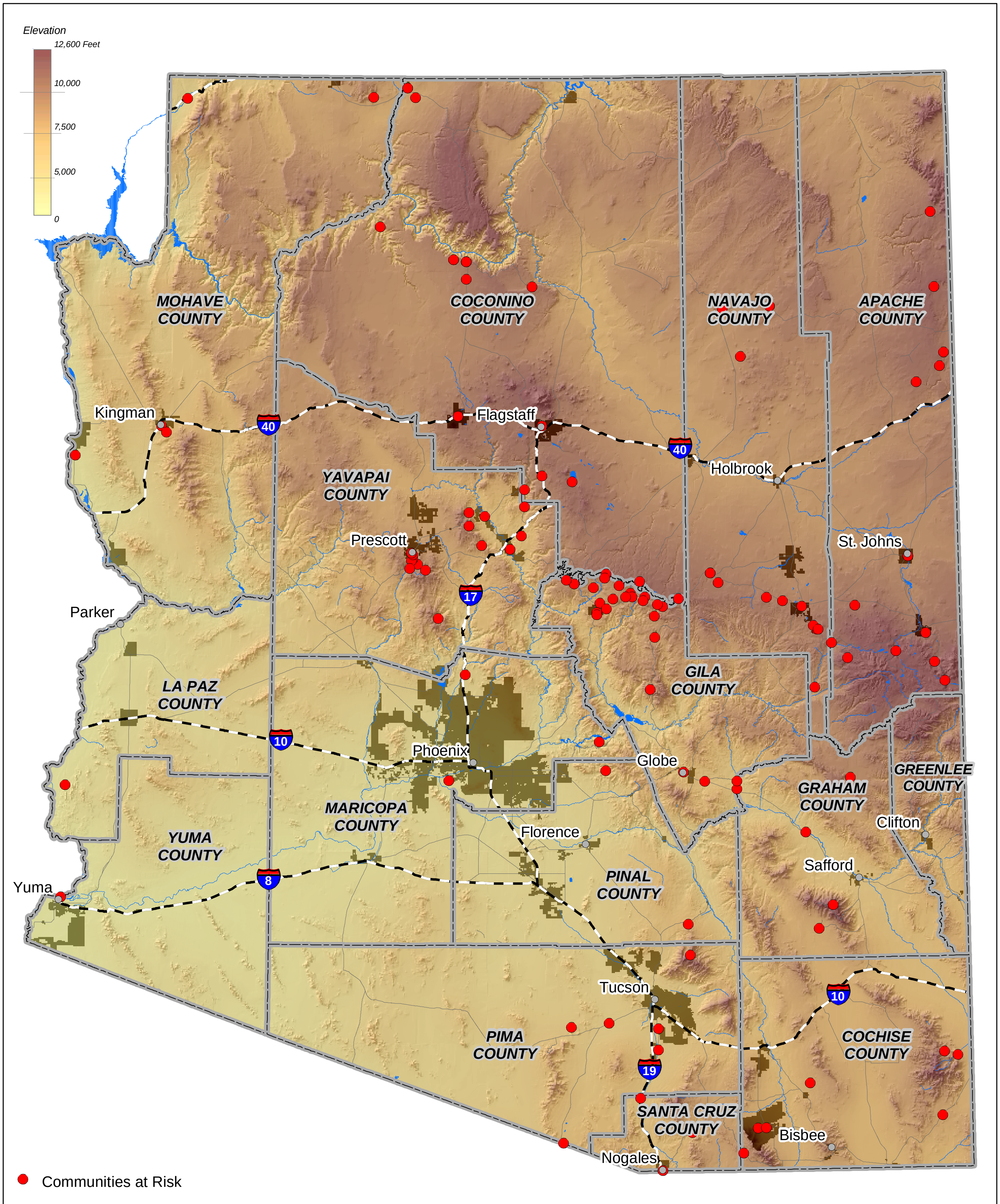
Table 7-26: Urban Wildland Interface Communities in Arizona by County	
County	**No. of Communities**
Apache	14
Cochise	7
Coconino	20
Gila	25
Graham	4
Greenlee	0
La Paz	1
Maricopa	3
Mohave	5
Navajo	15
Pima	7
Pinal	2
Santa Cruz	3
Yavapai	15
Yuma	1
Total	**122**

Source: Federal Register, August 17, 2001; URS, October 2003.

7.3.17.3.4 Other Arizona Wildfire Modeling and Risk Assessment Efforts

A couple of wildfire modeling efforts for large parts or all of Arizona are currently underway. These efforts are true risk assessments in that they consider probability and magnitude. These efforts are briefly outlined below.

- **Forest Ecosystem Restoration Analysis (ForestERA)**: The ForestERA Project is an effort of the Lab of Landscape Ecology and Conservation Biology at Northern Arizona University. The project aims to develop the capacity for landscape-scale analysis and carry out an integrated landscape assessment of ponderosa pine forests in northern Arizona. The project focuses on selected ponderosa habitat across north and central Arizona, current modeling efforts focused on the Greater Flagstaff region (two million acres) which will be expanded by December 2003. The goals of the fire modeling effort are to create data layers that will allow the prioritization of the timing and location of treatments designed to reduce fire threat, while also taking into consideration factors such as wildlife habitat. Under development are predictive models of fuel hazards and fire ignition risk to overlay with models of taxonomic distributions, inhabited areas, and other spatial data in order to facilitate management decisions (ForestERA, July 15, 2003).



Source: HAZUS99; ALRIS July 2001; Federal Register, Vol. 66, No. 60, August 2001; URS October 2003

LEGEND

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December 2003

State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-30

Urban Wildland Interface Communities in Arizona

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- **Wildfire Alternatives (WALTER)**: The WALTER project team is composed of faculty, staff, and graduate students from five different departments on the University of Arizona campus. The project seeks to improve understanding of the interactions among climate, fuels, fire history, and human factors that produce different kinds and levels of fire risk, and to devise innovative ways to deliver information to those who need it. The WALTER team is developing the first phase of an integrated model called Fire-Climate-Society (FCS-1) that integrates the climate and human dimensions of wildfire behavior for strategic management with more traditional mechanistic spatial wildfire models used for tactical management. FCS-1 draws from wide range of temporal and spatial data, including biophysical, socioeconomic and historical factors that will interact to produce maps of fire sensitivity (risk/probability of fire) and fire vulnerability (effects/consequences of fire). Ultimately the model will address two needs: strategic planning (using scenarios based on historic data to look at the past in order to plan for the future), and strategic management (using current climate analogs to generate longer-term "what if" scenarios). The emphasis of the model will be on identifying areas with the highest probability of wildfire, and will be designed to enhance rather than replace local expertise. The model will produce fire risk maps for four specific areas: Santa Catalina and Rincon Mountain Complex (Tucson area); Chiricahua Mountains (southeastern Arizona); Huachuca Mountains (Sierra Vista area); and Los Alamos, New Mexico and the Jemez Mountains, New Mexico (Grunberg).

In addition, a number of wildfire risk assessments that identify hazard areas (as opposed to modeling probability and magnitude) have also been conducted for specific parts of the state:

- **Arizona's Wildland Fire Hazard Mitigation Plan**: The Arizona Division of Emergency Management (ADEM) and the Arizona State Land Department (ASLD) led efforts to prepare this plan. The plan analyzes the wildfire challenge in Arizona and includes a review of six components of wildland fire mitigation: environmental constraints; interagency coordination; vegetation management; public education; responsibility in the wildland/urban interface; and regulatory considerations. Also included is a detailed map of the wildfire fuel hazard in the Prescott area, which acts as an example of what should be done for the entire state (ADEM and ASLD, June 22, 1995).

- **Greater Flagstaff Forests Partnership**: According to this organization, an assessment of the catastrophic fire risk within and immediately adjacent to Flagstaff has been done (an approximate 94,000 acre area) with the study area boundary within 1/2-1 mile of major developments (like Doney Park or Kachina Village) or city lands. Within the study area, approximately 23,000 acres of national forest, state and private lands have been identified as a high potential for catastrophic wildfire. Another 16,100 acres have been identified as a moderate risk. In addition, there are about 16,000 acres of highly urbanized residential/business acres, which have an unknown amount of high and moderate fire potential within them (Great Flagstaff Forests Partnership).

- **Upper San Pedro Watershed Wildfire Hazard Assessment and Mitigation Plan**: The San Pedro Riparian National Conservation Area, a 40-mile-long section of the San Pedro River managed by the Bureau of Land Management (BLM) in southern Arizona near Sierra Vista. The BLM funded work by the Safford/Tucson Fire Management Zone for a wildfire hazard assessment and mitigation plan for the lands in and adjacent to the National Conservation Area. The goal of the project was to evaluate the potential for wildfire and to identify specific actions to reduce the risk of loss of life, property, structures and riparian habitat. Wildfire hazard assessments were developed for six communities and three rural areas adjacent to the Conservation area (BLM, August 2003).

7.3.17.3.5 Wildfire Hazard in Arizona - FEMA / IFCI Methodology

In the absence of a statewide wildfire risk assessment model for Arizona, the approach specified by FEMA in *How-To #2: Understanding Your Risks -Identifying Hazards and Estimating Losses* for the identification of wildfire hazard areas have been followed, with a number of adjustments taken to account for Arizona specific factors. The FEMA methodology is the same as that specified from the International Fire Code Institute (IFCI) in the *Urban-Wildland Fire Interface Code 2000*.

To determine the risk of wildfire in Arizona it was necessary to determine what areas are the most susceptible and exposed to the greatest risk of wildfires. The *Urban-Wildland Interface Code* model relies on the relationship between the three primary fire potential factors to estimate fire hazard severity: topography, critical fire weather, and fuel availability. The relationship between these three factors and wildfire susceptibility is shown in Table 7-27.

Table 7-27: FEMA/IFCI Wildfire Susceptibility Matrix

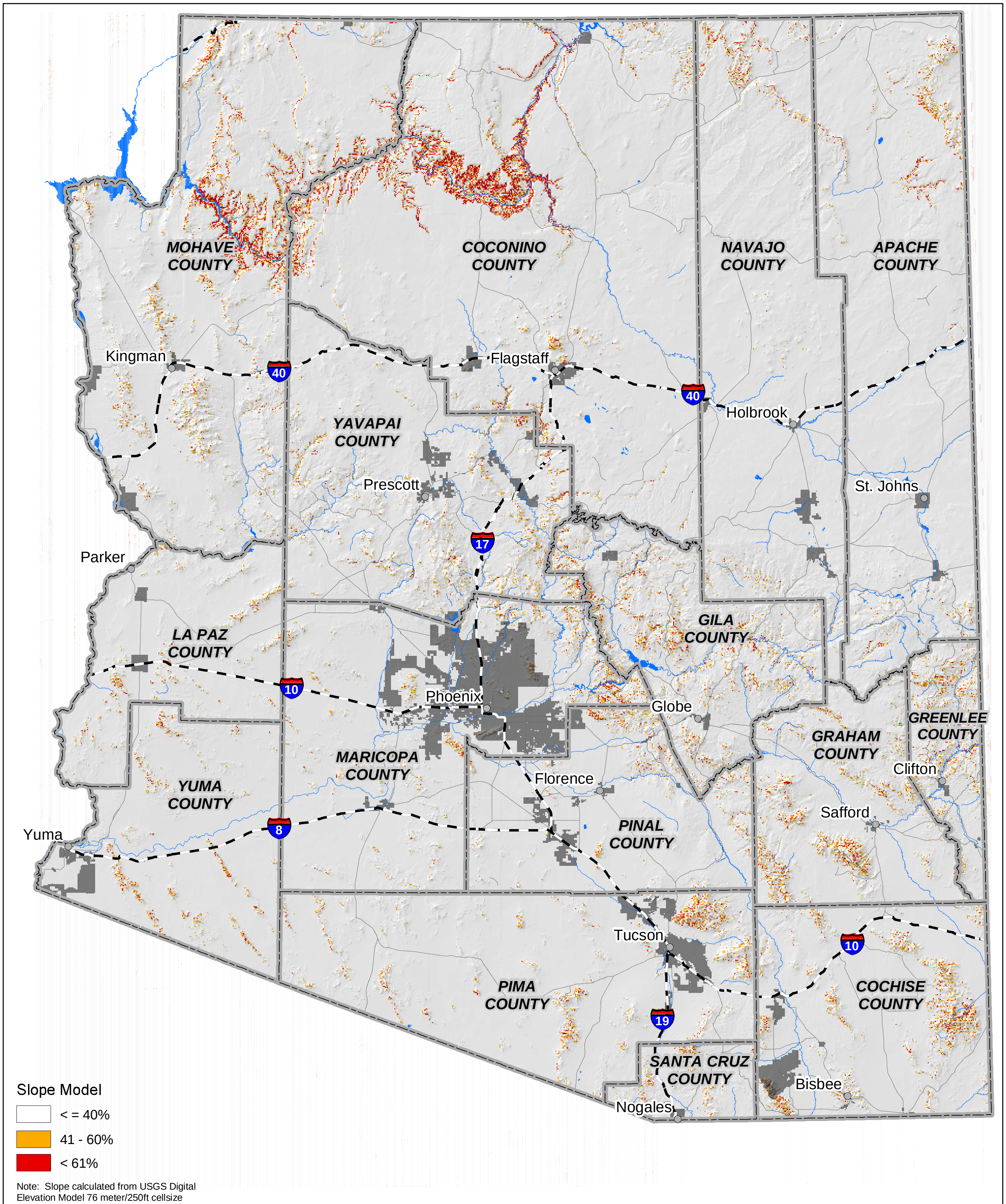
	Critical Fire Weather Frequency								
	<1 day per year			2-7 days per year			8+ days per year		
	Slope %			Slope %			Slope %		
Fuel Class	**<40**	**41-40**	**61+**	**<40**	**41-40**	**61+**	**<40**	**41-40**	**61+**
Light	M	M	M	M	M	M	M	M	H
Medium	M	M	H	H	H	H	E	E	E
Heavy	H	H	H	H	E	E	E	E	E

Note: M = Medium, H = High, E = Extreme.

Source: International Fire Code Institute, January 2000

The first factor, topography, was obtained from the State Digital Elevation Model (DEM). Steeper slopes generally increase fire velocity. The FEMA/IFCI model breaks slope into three broad classes: ≤ 40 percent, 41-60 percent, ≥ 61 percent. The U.S. Geological Survey Digital Elevation Model, 75meter/250 feet cell size was used to determine slope in Arizona. As shown in Figure 7-31, the majority of Arizona topography presents slopes of less than 40 percent slope. A belt of 40 percent to 60 percent slopes follows the Mogollon Rim region. The Grand Canyon and other lesser canyons have slopes exceeding 60 percent.

The second factor, critical fire weather frequency, proved more difficult to evaluate due to the apparent unavailability of long-term GIS coverage/data for the state. Discussions with the Arizona Hazard Mitigation Plan Team indicated that it was reasonable to assume that Arizona experiences over eight critical fire weather days per year.



Source: HAZUS99; ALRIS July 2001; USGS; URS October 2003

LEGEND

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- City
- Major Stream
- County
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Figure 7-31

Slope Model of Arizona

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For the third factor, as recommended by FEMA, the US Forest Service's National Fire Danger Rating System (NFDRS) fuel model dated July 1999 was used. The NFDR fuel models have been mapped in raster format across the lower 48 states at 1 km resolution, derived from satellite imagery and ground sampling that can be converted into GIS format.

The NFDRS fuel models describe twenty regional vegetative biomes which are assigned a model letter (e.g., A, B, C). Not all 20 NFDRS models were mapped. Fuel model E (hardwoods after leaf fall) was not used. Only model R was used for hardwoods because the live load can be transferred between the live and dead vegetation classes as a function of changes in vegetation greenness as observed from satellites. The slash fuel models (I, J, and K) were not used because the location, extent and condition of activity fuels changes relatively quickly.

Each NFDRS fuel model was then classified as heavy, medium or light fuel based upon availability, moisture content, and continuity. The classification scheme is contained in *FEMA's How-To #3: Understanding Your Risks*.

Note, however, that the NFDRS system acknowledges that local conditions can vary significantly from the regional model descriptions and where such variations occur, fuel classifications may be refined to more closely reflect actual site conditions. In some areas, Arizona conditions appear to vary from the models as mapped under the NFDR system. Two areas where modifications appear warranted and have been made are listed below:

- The Mogollon Rim was classified under the NFDRS as "open" ponderosa stands or fuel model C (which is light fuel under the FEMA/ICFI methodology). Upon closer examination, the Mogollon Rim region has vast, "closed" stands of ponderosa pine (fuel model U which is heavy fuel under the FEMA/ICFI methodology).

- Much of northeastern and southeastern Arizona is classified under the NFDR system as F which is medium fuel, while a careful reading of the model reveals that fire activity in fuel model F is overrated at low wind speeds and in areas of sparse ground fuels. It appears reasonable that the pinyon-juniper and oak scrub portions of northeastern and southeastern Arizona generally have sparse ground fuels and, therefore, the NFDRS model F risk is overstated and warrants refinement to light fuel.

In addition, the NFDRS fuel model does not identify or exclude areas that are urbanized. In order to avoid overstating the wildfire danger in highly urbanized areas, two additional screens were conducted:

- Detailed existing land use layers for Maricopa County and Pima County were obtained. Only polygons greater than 10 acres in size with the following land uses were included: vacant; parks and recreation; and forests. All other existing land use polygons were identified as urban.

- For the remainder of Arizona, Census 2000 data was used. Only census blocks with less than two persons per acre were included. All other census blocks were identified as urban.

The Arizona fuel model, with the modifications described above, is shown in Figure 7-32. Clearly visible as heavy fuel are the Mogollon Rim across the central and northern portion of the state as well as the "sky island" mountains.

By combining the three factors, topography, critical fire weather frequency, and fuel using the matrix in Table 7-27, it was possible to produce the wildfire hazard areas map shown in Figure 7-33. The map shows a close correspondence between the heavy fuel model and the areas of extreme wildfire susceptibility. The area of wildfire hazard by rating for each county is shown in Table 7-28. Nearly one-quarter of the state (28,360 acres or 24.9 percent) has a wildfire hazard rating of extreme, with large portions of Apache, Coconino, Gila, Graham, Greenlee, Mohave, Navajo, and Yavapai Counties affected.

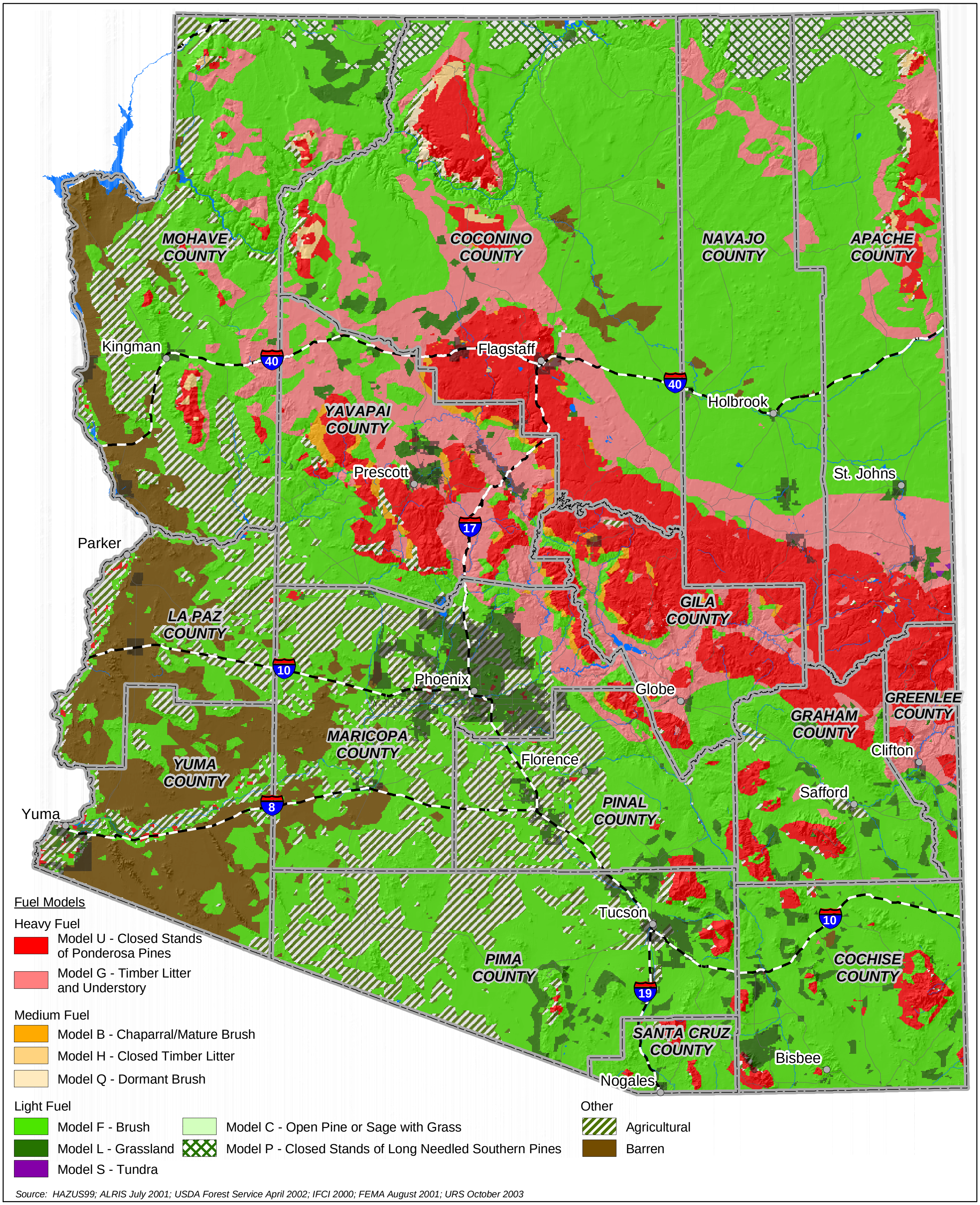
Table 7-28: Wildfire Hazard Rating in Arizona by County				
County	Total Square Miles	Square Miles in Hazard Rating …		
		Extreme	High	Medium
Apache	11,216	4,158	12	6,968
Cochise	6,215	522	22	5,609
Coconino	18,644	6,800	307	11,011
Gila	4,792	3,861	10	888
Graham	4,649	1,276	21	3,203
Greenlee	1,836	1,340	2	492
La Paz	4,517	39	3	1,265
Maricopa	9,222	793	10	3,689
Mohave	13,480	1,720	205	7,132
Navajo	9,952	2,354	24	7,528
Pima	9,184	248	18	5,663
Pinal	5,371	369	15	3,202
Santa Cruz	1,236	124	4	1,017
Yavapai	8,125	4,690	6	2,758
Yuma	5,523	66	3	1,346
Total	**113,962**	**28,360**	**662**	**61,771**
Source: NFDRS, July 1999; IFCI, 2000; FEMA, August 2001; URS, October 2003.				

7.3.17.4 Warning Time

The warning time provided by wildfire warnings is typically on the order of days, providing sufficient time for people to evacuate potential hazard areas. Major wildfire warning services are provided by the Wildland Fire Assessment System (WFAS) and the National Weather Service (NWS).

- **National Fire Danger Rating System (NFDRS)**: Every day during the fire season, national maps of selected fire weather and fire danger components of the National Fire Danger Rating System (NFDRS) are produced by the Wildland Fire Assessment System (WFAS) at the USDA Forest Service Rocky Mountain Research Station in Missoula, Montana. The maps characterize fire danger by evaluating the approximate upper limit of fire behavior in a fire danger rating area during a 24-hour period. The NFDRS uses computer programs and algorithms based on fuels, topography and weather to estimate short-term (today and tomorrow) fire danger for a given rating area. NFDRS fire danger is rated by evaluating the approximate upper limit of fire behavior in a fire danger rating area during a 24-hour period. The ratings are for the potential growth and behavior of a wildfire. They are used to guide presuppression activities and the selection of appropriate level of initial response to a reported wildfire (in lieu of detailed, site- and time-specific information). In essence, the ratings link an organization's readiness level (or pre-planned fire suppression actions) to the fire problems of the day (NWS).

  Note that the NFDRS relates only to the potential of an initiating fire, one that spreads without crowning or spotting, through uniform fuels on a continuous slope. It measures fire only from a containment standpoint as opposed to full extinction. In addition, the NFDRS represents near worst-case conditions measured at exposed locations at or near the peak of the normal burning period. Also note that the NFDRS is a broad scale rating, approximately for 100,000 acres. Besides the basic fire danger ratings of low, moderate, high, very high and extreme, the NFDRS calculates parameters to aid agencies in determining staffing levels, how hot a fire will burn and spread, ignition component and flame length. One possible outcome of a high fire danger is an agency may have to ban campfires or prescribed burning on federal lands.



LEGEND

- Interstate
- Highway
- City
- Major Stream
- County
- Lake
- County Seat

0 25 50
Miles

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December 2003

Figure 7-32

State of Arizona Enhanced Hazard Mitigation Plan

Modified National Fire Danger Rating (NFDR) System Fuel Model of Arizona

URS

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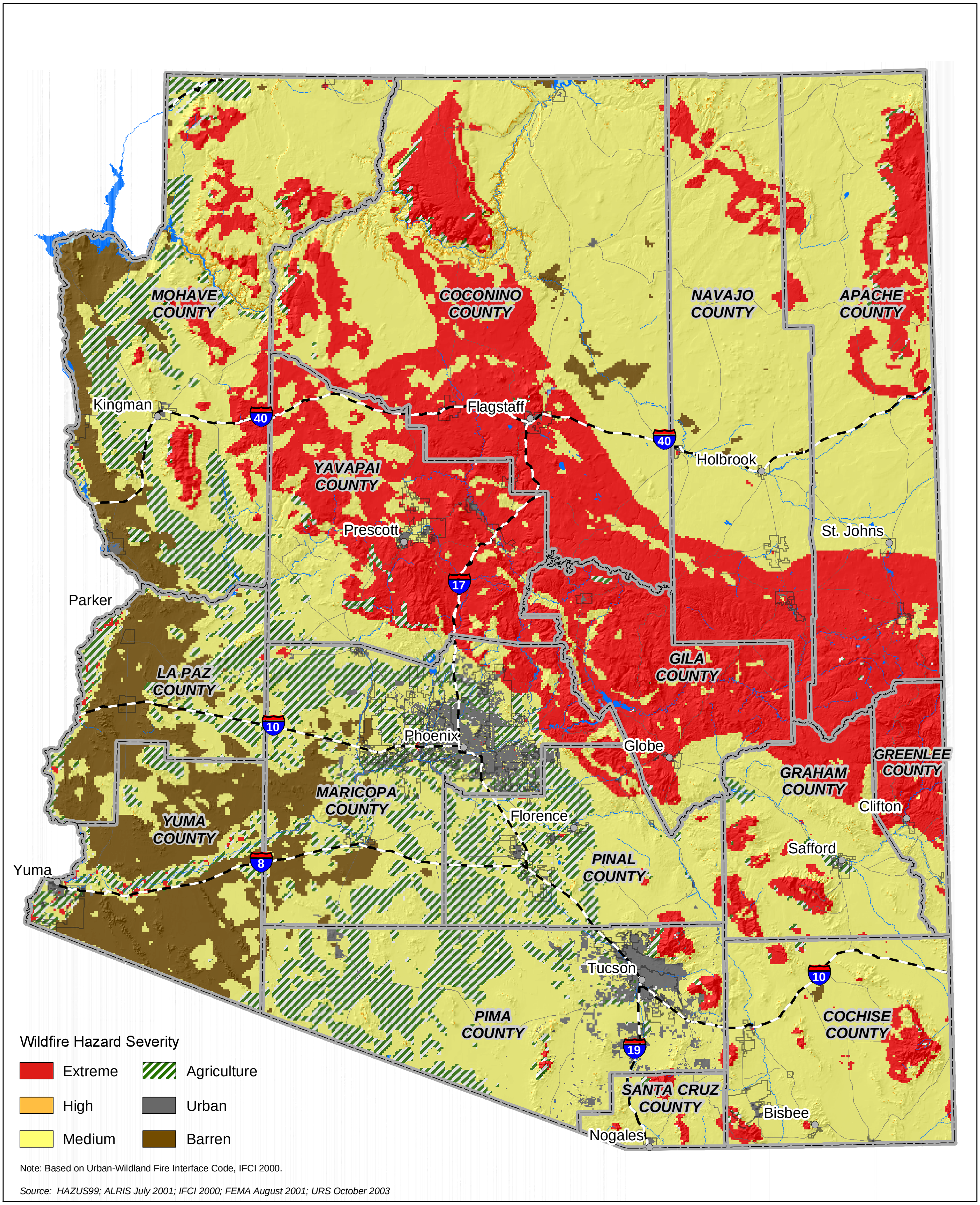

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State of Arizona Enhanced Hazard Mitigation Plan

Figure 7-33

Wildfire Hazard Areas in Arizona

URS

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December 2003

In addition to the NFDRS warnings, the NWS prepares fire weather warnings for localized areas. Arizona has three NWS forecast offices, respectively, in Flagstaff, Phoenix, and Tucson. These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories). These offices may issue the following wildfire warnings:

- **Fire Weather Zones:** Complete fire weather forecasts for states or forecast regions. These forecasts are prepared twice daily during fire weather season, and once daily during the off season. This forecast is used for day-to-day planning of land management operations and for determining general weather trends which might impact fire behavior.

- **Fire Weather Spot Forecasts**: Special point fire weather forecasts made for controlled burns or wildfires. Spot forecasts are special, non-routine forecasts prepared upon request from user agencies that need site-specific weather forecasts in order to control the spread of wildfire, plan and manage prescribed fires, or other specialized forest management activities.

- **Fire Weather Statements, Watches and Warnings**: During periods in which critical fire weather conditions are expected or are imminent, the NWS will issue statements, watches and warnings to describe the level of urgency to the appropriate user agencies and the public. These are coordinated with the land management agencies.

- **Red Flag Warning / Event**: Special forecast issued when red flag conditions exist or are highly probable and the forecast time of onset is less than 24 hours. A Red Flag Event occurs when critical weather conditions develop which could lead to extensive wildfire occurrences or to extreme fire behavior. Red Flag Events represent a hazard to life and property and may adversely impact fire fighting personnel and resources. Critical weather conditions include combinations of the following: strong, gusty wind; very low relative humidity; highly unstable atmosphere; significant wind shifts; lightning. Typically, these weather conditions must be coupled with very low fuel moistures.

- **Fire Danger Statements and Blow-Up Alerts:** When fire danger or fire occurrence is high and is coupled with critical weather conditions, the U.S. Forest Service or state land management agencies may request that the NWS issue a Fire Danger Statement or Blow-Up Alert.

It should also be noted that longer-term forecasts are also made, typically prior to the fire season. An example is the *Long-Range Fire Risk Assessment, Southwest Geographic Area, 2003 Fire Season* (Heckman et al, April 30, 2003).

7.3.18 Winter Storm

7.3.18.1 Nature

Severe winter storms can cause unusually heavy rain or snowfall, high winds, extreme cold, and ice storms throughout the continental United States. In the West, winter storms begin with cyclonic weather systems in the North Pacific Ocean or the Aleutian Islands that can cause massive low pressure storm systems to sweep across the western states, including Arizona. Winter storms plunge southward from arctic regions and drop heavy amounts of snow and ice.

Winter storm occurrences tend to be very disruptive to transportation and commerce. Trees, cars, roads, and other surfaces develop a coating or glaze of ice, making even small accumulations of ice extremely hazardous to motorists and pedestrians. The most prevalent impacts of heavy accumulations of ice are slippery roads and walkways that lead to vehicle and pedestrian accidents; collapsed roofs from fallen trees and limbs and heavy ice and snow loads; and felled trees, telephone poles and lines, electrical wires, and communication towers. As a result of severe ice storms, telecommunications and power can be disrupted for days. Such storms can also cause exceptionally high rainfall that persists for days, resulting in heavy flooding.

7.3.18.2 History

Winter storms are among the worst non-tropical storm events in the United States. For example, the Superstorm of March 1993 killed approximately 80 people, injured more than 600, and caused more than $2 billion across 20 eastern states (FEMA, 1997).

A total of 17 winter storms affecting Arizona were identified, as shown in Table 7-3, which resulted in a total of 17 fatalities, 16 injuries, and $2.1 million in damages were identified for all winter storms. A disaster/emergency declaration made for 8 winter storms. The following are some of the largest winter storms in Arizona's history:

- In December 1967, a huge winter storm paralyzed northern Arizona and brought snow to much of the state. It was actually two storms, with the second following closely on the heels of the first, ultimately resulting in the death of eight people due to exposure. During the nine day period, snowfall totals in north and central Arizona included 102.7 inches at Hawley Lake, 99.0 inches at Greer, 91.5 inches at the Heber Ranger Station, 87.3 inches at Crown King, 86.0 inches at Flagstaff, 77.0 inches at Payson, 46.0 inches at Prescott, 39.6 inches at Winslow, 33.5 inches at Window Rock,32.5 inches at Sedona, and 31.0 inches at the South Rim of the Grand Canyon. The Navajo Nation was extremely hard hit as two to three feet of snow fell across the community. On December 14, a state 24-hour snowfall record of 38.0 inches fell at the Heber Ranger Station. Southern Arizona did not escape, with 84.0 inches on Mt. Lemmon, 27.5 inches at Miami, 17.7 inches at Wilcox, 11.0 inches at Safford, 5.0 inches at Wickenburg, 3.8 inches at Douglas, 3.0 inches at Ajo, 2.5 inches at Gila Bend, and 1.6 inches at Tucson, and measurable snow fall on the lowest deserts (ADEM, December 2001).

- On January 4, 1995, a winter storm caused heavy rains over much of central and southeastern Arizona, resulting in an estimated $2.0 million in damages. Reported rainfall included 3.5 inches at Magma, 2.33 inches at Payson, 2.08 inches at Pinetop, 2.01 inches at Globe, and 1.83 inches at Sedona. Some unbridged road crossings in the Safford area were also damaged (NCDC Storm Event Database, January 2003).

- In January 1997, a winter storm created snowfall at unusually low elevations across southern Arizona. A trace of snow was recorded at Tucson, and 4 to 10 inches at elevations between 4,000 and 6,000 feet. The storm closed schools, stranded many motorists, caused broken water pipes, and caused the fatality of many ostriches at commercial farms, resulting in an estimated $100,00 in damages (NCDC Storm Event Database, January 2003).

- In March 2000, a winter storm dropped between 1 and 1 1/2 inches of rain in the Tucson area, with nearby mountains receiving about 24 inches of snow. Temperatures hovered around freezing and approximately 500 illegal aliens surrendered themselves to nearby homes or passing motorists. Wearing only t-shirts and using plastics bags as rain gear they were treated for various stages of hypothermia and injuries they received while walking through the desert. Two fatalities and ten injuries from exposure were reported in an area 50 miles southwest of Tucson (NCDC Storm Event Database, January 2003).

- In November 2001, the first storm of the season with measurable snow caused dozens of rush-hour traffic accidents along the Mogollon Rim, resulting in 1 fatality and 5 injuries. Most of the accidents occurred on Flagstaff City streets as the roads became snow packed and icy. City police handled more than 40 accident calls. County officials reported less than ten accidents. Jack-knifed semis caused east bound traffic on I-40 to come to a standstill 5 miles east of Williams. There was a fatal crash on I-40 three miles east of Seligman (NCDC Storm Event Database, January 2003).

7.3.18.3 Probability and Magnitude

Snow level measurements are recorded daily across the United States and can be used to estimate the probability and frequency of severe winter storms. In Arizona, there is a 5 percent annual chance that snow depths between zero and 25 centimeters will be exceeded, a snowfall probability that is among the lowest in the nation (FEMA, 1997). However, as noted above and in Table 7-29, snowfall extremes can occur in Arizona and have serious.

Table 7-29: Snowfall Records in Arizona

Event	Amount	Date	Location
Record Maximum Winter Snowfall	400.9"	1972-73	Sunrise Mountain
Record Maximum 1-Day Snowfall	38.0"	14 December 1967	Heber Ranger Station
Highest Average Annual Snowfall	243.0"	--	Sunrise Mountain

Source: Office of the State Climatologist for Arizona.

7.3.18.4 Warning Time

Unfortunately, there is no universal answer for every severe weather event. Warning times vary based on storm location, direction, intensity, and duration. Before watches and warnings are issued, the NWS, private forecasters, newspapers, radio and television normally try to alert the public to potential weather dangers. Often, forecasters begin issuing severe weather statements, advisories, or bulletins on hurricanes and winter storms three or four days before the storm hits. Usually, the NWS Storm Prediction Center sends out alerts the day before dangerous weather is likely. Most television weathercasters highlight these alerts on the evening news the day before threatening weather. All severe weather broadcasts covering Arizona originate from NWS offices in Tucson, Phoenix, Flagstaff, and Las Vegas, Nevada.

These offices provide a wide range of weather related information, including current conditions, regional weather forecasts, and storm information (e.g., watches, warnings, statements, or advisories). The warning time provided by a winter storm watch is on the order of days, while a winter storm warning typically provides warning time of 24 hours. This time should be sufficient for people to move to safety, although damage from a winter storm may still be significant. Experience has show though that no area can fully prepare for severe winter storms.

ACRONYMS

ACERP	Arizona Comparative Environmental Risk Project
AAWE	American Association for Wind Engineering
ADA	Arizona Department of Agriculture
ADEMA	Arizona Department of Emergency and Military Affairs
ADEM	Arizona Division of Emergency Management (a division of ADEMA)
ADEQ	Arizona Department of Environmental Quality
AGFD	Arizona Game and Fish Department
AL	Annualized Loss
ANSI	American National Standards Institute
APA	American Planning Association
ARS	Arizona Revised Statutes
ASCE	American Society of Civil Engineers
ASLD	Arizona State Land Department
ASU	Arizona State University
BLM	Bureau of Land Management
CAP	Central Arizona Project
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DFIRM	Digital Flood Insurance Rate
DMA 2000	Disaster Mitigation Act of 2000
EHS	Extremely Hazardous Substance
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
FEMA	Federal Emergency Management Agency
HAZMAT	Hazardous Material
HAZUS-99	Hazards United States1999
HAZUS-MH	Hazards United States Multi-Hazard
HUD	Department of Housing and Urban Development
IOM	Institute of Medicine
LEPC	Local Emergency Planning Committee
MCDEM	Maricopa County Department of Emergency Management

MCFlood	Maricopa County Flood Control District
MMI	Modified Mercalli Intensity
NCDC	National Climate Data Center
NESDIS	National Environmental Satellite, Data and Information Service
NFIP	National Flood Insurance Program
NHC	National Hurricane Center
NIBS	National Institute of Building Services
NID	National Inventory of Dams
NIST	National Institute of Standards and Technology
NFIP	National Flood Insurance Program
NSF	National Science Foundation
NOAA	National Oceanic and Atmospheric Administration
NRC	National Response Center
NWS	National Weather Service
OIE	Office International des Epizooties
PSDI	Palmer Drought Severity Index
RL	Repetitive Loss
SARA	Superfund Amendments and Reauthorization Act
SERC	State Emergency Response Commission
SRP	Salt River Project
UBC	Uniform Building Code
URS	URS Corporation
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WMD	Weapon(s) of Mass Destruction

DEFINITIONS

Actions: Specific actions that help achieve goals and objectives. Multiple mitigation actions may be defined to feed into an evaluation of the alternative actions.

Arson: The act of willfully and maliciously burning of property, especially with criminal or fraudulent intent.

Asset: Any natural or human-made feature that has value, including, but not limited to people; buildings; infrastructure like bridges, roads, and sewer and water systems; lifelines like electricity and communication resources; or environmental, cultural, or recreational features like parks, dunes, wetlands, or landmarks.

Avalanche: Avalanches are massive downward and outward movements of slope-forming materials. These masses may range from car-size to entire mountainsides and includes movement of snow, ice, and debris moving rapidly enough to threaten life. Snow avalanches are caused by the added weight of fresh snow or by gradual weakening of older snow and are often triggered by recreational activity or the impact of small masses of snow or ice falling from above. Three main factors determine whether avalanches are likely to occur - the weather, snow pack, and terrain. There are two principal types of avalanches: a loose snow avalanche gathers more and more snow as it descends a mountainside; a slab avalanche consists of more compact, cohesive snow and ice that breaks away from the slope in a discrete mass. The latter type is responsible for the great majority of accidents.

Biological Hazards: A hazard caused by the presence of any micro-organism, virus, infectious substance, or biological product that may be engineered as a result of biotechnology or any naturally occurring micro-organism, virus, infectious substance, or biological product, capable of causing death, disease, or other biological malfunction.

Building: A structure that is walled and roofed, principally above ground and permanently affixed to a site. The term includes a manufactured home on a permanent foundation on which the wheels and axles carry no weight.

Building / Structure Collapse: The failure and downfall of a structure. The collapse may result from a variety of natural causes such as hurricanes, earthquakes, tornadoes, floods, or from manmade circumstances such as construction deficiencies, neglect, aging infrastructure, or acts of terrorism.

Civil Disobedience: The refusal to obey civil laws or decrees, usually taking the form of passive resistance. People practicing civil disobedience break a law because they consider the law unjust, want to call attention to its justice, and hope to bring about its repeal or amendment. They are also willing to accept a penalty for breaking the law.

Civil Disturbance: When individuals or segments of the population create a situation, often a result of civil unrest, requiring a response from the emergency response community to protect lives and property. The disturbance may be small and isolated to a small area or be of a larger scale and exceeding the response capabilities of a jurisdiction. Activities are normally active (demonstrations, looting, riots) rather than passive (public speeches, sit-downs, marches).

Civil Unrest: When a segment of the civil population indicates its discontent or dissatisfaction with existing political, social, or religious issues. The unrest may materialize as a civil disturbance or civil disobedience. Activities may be passive (public speeches, sit-downs, marches) or active (demonstrations, looting, riots).

Consequences: The damages (full or partial), injuries, and losses of life, property, environment, and business that can be quantified by some unit of measure, often in economic or financial terms.

Critical Facilities and Infrastructure: Systems or facilities whose incapacity or destruction would have a debilitating impact on the defense or economic security of the nation. The Critical Infrastructure Assurance Office (CIAO) defines eight categories of critical infrastructure, as follows:

- Telecommunications infrastructure: Telephone, data services, and Internet communications, which have become essential to continuity of business, industry, government, and military operations.

- Electrical power systems: Generation stations and transmission and distribution networks that create and supply electricity to end-users.
- Gas and oil facilities: Production and holding facilities for natural gas, crude and refined petroleum, and petroleum-derived fuels, as well as the refining and processing facilities for these fuels.
- Banking and finance institutions: Banks, financial service companies, payment systems, investment companies, and securities/commodities exchanges.
- Transportation networks: Highways, railroads, ports and inland waterways, pipelines, and airports and airways that facilitate the efficient movement of goods and people.
- Water supply systems: Sources of water; reservoirs and holding facilities; aqueducts and other transport systems; filtration, cleaning, and treatment systems; pipelines; cooling systems; and other delivery mechanisms that provide for domestic and industrial applications, including systems for dealing with water runoff, wastewater, and firefighting.
- Government services: Capabilities at the federal, state, and local levels of government required to meet the needs for essential services to the public.
- Emergency services: Medical, police, fire, and rescue systems.

Dam / Levee Failure: Dam/levee failure can be caused by natural occurrences such as floods, rock slides, earthquakes, or the deterioration of the foundation or the materials used in construction. Usually the changes are slow and not readily discovered by visual examination. Such a failure presents a significant potential for a disaster in that significant loss of life and property would be expected in addition to the possible loss of power and water resources.

Department of Homeland Security (DHS): Following the September 11, 2001 terrorist attacks, President George W. Bush created a new federal government department in order to bring 22 previously separate domestic agencies together. The new department's first priority is protecting the nation against further terrorist attacks. Component agencies analyze threats and intelligence, guard borders and airports, protect critical infrastructure, and coordinate the response for future emergencies. The new department is organized into five major directorates: Border and Transportation Security (BTS); Emergency Preparedness and Response (EPR); Science and Technology (S&T); and Information Analysis and Infrastructure Protection (IAIP); Management. In addition, several other critical agencies have been folded into the new department or are newly created. The Federal Emergency Management Agency (FEMA) is the foundation of the Emergency Preparedness and Response (EPR) Directorate.

Disaster Mitigation Act of 2000 (DMA2K): A law signed by the President on October 30, 2000 that encourages and rewards local and state pre-disaster planning, promotes sustainability as a strategy for disaster resistance, and is intended to integrate state and local planning with the aim of strengthening statewide mitigation planning.

Drought: A drought occurs when water supplies cannot meet established demands. "Severe" to "extreme" drought conditions endanger livestock and crops, significantly reduce surface and ground water supplies, increase the potential risk for wildland fires, increase the potential for dust storms, and cause significant economic loss. Humid areas are more vulnerable than arid areas. Drought may not be constant or predictable and does not begin or end on any schedule. Short term droughts are less common due to the reliance on irrigation water in arid environments.

Dust / Sand Storms: A dust or sand storm is a severe windstorm that sweeps clouds of dust across an arid region. They can be hazardous to transportation and navigation and to human health. Severe or prolonged dust and sand storms can result in disasters causing extensive economic damage over a wide area and personal injury and death. In Arizona, dust or sand storms are generally associated with the advance of a thunderstorm.

Earthquake: An earthquake is a naturally-induced shaking of the ground, caused by the fracture and sliding of rock within the Earth's crust. The magnitude is determined by the dimensions of the rupturing fracture (fault) and the amount of displacement that takes place. The larger the fault surface and displacement, the greater the energy. In addition to deforming the rock near the fault, this energy produces the shaking and a variety of seismic waves that radiate throughout the Earth. Earthquake magnitude is measured using the Richter Scale and earthquake intensity is measured using the Modified Mercalli Intensity Scale.

Emergency Preparedness and Response (EPR) Directorate: One of five major Department of Homeland Security Directorates which builds upon the formerly independent Federal Emergency Management Agency (FEMA). EPR is responsible for preparing for natural and man-made disasters through a comprehensive, risk-based emergency management program of preparedness, prevention, response, and recovery. This work incorporates the concept of disaster-resistant communities, including providing federal support for local governments that promote structures and communities that reduce the chances of being hit by disasters.

Emergency Response Plan: A document that contains information on the actions that may be taken by a governmental jurisdiction to protect people and property before, during, and after a disaster.

Enemy Attack: The use of aggressive action against an opponent in pursuit of an objective. An "enemy attack" is considered an attack of one sovereign government against another as either a declared or undeclared act of war.

Explosion / Fire: An explosion is the sudden loud release of energy and a rapidly expanding volume of gas that occurs when a gas explodes or a bomb detonates. Explosions result from the ignition of volatile products such as petroleum products, natural and other flammable gases, hazardous materials/chemicals, dust, and bombs. While an explosion surely may cause death, injury and property damage, a fire routinely follows which may cause further damage and inhibit emergency response.

Exposure: The number, types, qualities, or monetary values of various types of property or infrastructure and life that may be subject to an undesirable or injurious hazard event.

Extreme Air Pollution: Pollution is the contamination of the earth's environment with materials that interfere with human health, the quality of life, or the natural functioning of ecosystems. Air pollution is the addition of harmful substances to the atmosphere. It makes people sick, causing breathing problems and sometimes cancer, and it harms plants, animals, and the ecosystems in which they live. Some pollutants return to earth in the form of acid rain and snow that corrodes structures, damages vegetation, and makes streams and lakes unsuitable for life. "Extreme air pollution" exceeds established thresholds resulting in the need to take corrective actions and cause the public to take precautions.

Extreme Cold: Extreme cold is associated with either polar regions or extreme winter storms. Communities in polar regions are less threatened as they are normally prepared to cope with extreme cold. The extreme cold associated with winter storms is a deceptive killer as it indirectly causes injury and death resulting from exhaustion and overexertion, hypothermia and frostbite from wind chill, and asphyxiation.

Extreme Heat: Extreme heat is defined as temperatures that hover ten degrees or more above the average high temperature for the region and last for several weeks. Humid conditions may also add to the discomfort of high temperatures. Excessively dry and hot conditions can provoke dust storms and low visibility.

Federal Emergency Management Agency (FEMA): Formerly independent agency created in 1978 to provide a single point of accountability for all Federal activities related to disaster mitigation and emergency preparedness, response and recovery. As of March 2003, FEMA is a part of the Department of Homeland Security's Emergency Preparedness and Response (EPR) Directorate.

Flood Insurance Rate(FIRM): of a community, prepared by FEMA, that shows the special flood hazard areas and the risk premium zones applicable to the community.

Fuel / Resource Shortage: A fuel/resource shortage is defined as an actual or potential shortage of natural gas, crude and refined petroleum, petroleum-derived fuels, or other critical commodities that significantly impacts the ability to: render essential government and emergency services (medical, fire, safety); and threatens the health and safety of the public.

Frequency: A measure of how often events of a particular magnitude are expected to occur. Frequency describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs, on average. Statistically, a hazard with a 100-year recurrence interval is expected to occur once every 100 years on average, and would have a 1 percent chance – its probability – of happening in any given year. The reliability of this information varies depending on the kind of hazard being considered. Probability is a related term.

Fujita Scale of Tornado Intensity: Rates tornadoes with numeric values from F0 to F5 based on tornado winds peed and damage sustained. An F0 indicates minimal damage such as broken tree limbs or signs, while an F5 indicates severe damage sustained.

Geographic Information Systems (GIS): A computer software application that relates physical features on the earth to a database to be used for mapping and analysis.

Goals: General guidelines that explain what you want to achieve. Goals are usually broad statements with long-term perspective.

Hazard: A source of potential danger or adverse condition. Hazards include both natural and man-made events. A natural event is a hazard when it has the potential to harm people or property and may include events such as floods, earthquakes, tornadoes, tsunami, coastal storms, landslides, and wildfires that strike populated areas. Man-made hazard events originate from human activity and may include technological hazards and terrorism. Technological hazards arise from human activities and are assumed to be accidental and/or have unintended consequences (e.g., manufacture, storage and use of hazardous materials). While no single definition of terrorism exists, the Code of Federal Regulations defines terrorism as "…unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives."

Hazard Event: A specific occurrence of a particular type of hazard.

Hazard Identification: The process of identifying hazards that threaten an area.

Hazard Mitigation: Cost effective measures taken to reduce or eliminate long-term risk associated with hazards and their effects.

Hazard Profile: A description of the physical characteristics of hazards and a determination of various descriptors including magnitude, duration, frequency, probability, and extent.

Hazardous Materials Incidents: A spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping or disposing into the environment of a hazardous material, but excludes: (1) any release which results in exposure to poisons solely within the workplace, with respect to claims which such persons may assert against the employer of such persons; (2) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft, vessel, or pipeline pumping station engine; (3) release of source, byproduct, or special nuclear material from a nuclear incident; and (4) the normal application of fertilizer.

HAZUS: A GIS-based nationally standardized earthquake loss estimation tool developed by FEMA.

Hostage Situation: A situation in which people are held hostage and negotiations take place for their release. The situation may range from a simple domestic or isolated criminal act to an attempt to impose will on a national or international scale to intimidate or coerce a government to further a political, social, or religious objective.

Hysteria (Mass): Also known as "mass psychogenic illness" and "hysterical contagion," mass hysteria is a situation in which a symptom or set of symptoms for which there is no physical explanation spreads quickly among a group. It may occur as a reaction to an incident of domestic terrorism.

Implementation Strategy: A comprehensive strategy that describes how the mitigation actions will be implemented.

Infestations: An infestation consists of an invasion or spreading of a living organism (plant, animal, etc.) that has an adverse (unwanted) effect on the population or the environment. The effect may range from a simple nuisance to an infectious disease or destructive parasite or insect. Infestations may result from non-indigenous plants, rodents, weeds, parasites, insects, and fungi, and may adversely affect people, animals, agriculture, economy (e.g., tourism), and property.

Liquefaction: The phenomenon that occurs when ground shaking (earthquake) causes loose soils to lose strength and act like viscous fluid. Liquefaction causes two types of ground failure: lateral spread and loss of bearing strength.

Landslides / Mudslides: Landslides, like avalanches are massive downward and outward movements of slope-forming materials. The term landslide is restricted to movement of rock and soil and includes a broad range of velocities. Slow movements, although rarely a threat to life, can destroy buildings or break buried utility lines. A landslide occurs when a portion of a hill slope becomes too weak to support its own weight. The weakness is generally initiated when rainfall or some other source of water increases the water content of the slope, reducing the shear strength of the materials. A mud slide is a type of landslide referred to as a flow. Flows are landslides that behave like fluids: mud flows involve wet mud and debris.

Mitigate: To cause to become less harsh or hostile; to make less severe or painful. Mitigation activities are actions taken to eliminate or reduce the probability of the event, or reduce its severity of consequences, either prior to or following a disaster/emergency.

Mitigation Plan: A systematic evaluation of the nature and extent of vulnerability to the effects of natural hazards typically present in a defined geographic area, including a description of actions to minimize future vulnerability to hazards.

Modified Mercalli Intensity Scale: The Modified Mercalli Intensity Scale is commonly used in the United States by seismologists seeking information on the severity of earthquake effects. Intensity ratings are expressed as Roman numerals between I at the low end and XII at the high end. The Intensity Scale differs from the Richter Magnitude Scale in that the effects of any one earthquake vary greatly from place to place, so there may be many Intensity values (e.g.: IV, VII) measured from one earthquake. Each earthquake, on the other hand, should have just one Magnitude, although the several methods of estimating it will yield slightly different values (e.g.: 6.1, 6.3).

Monsoon: A monsoon is any wind that reverses its direction seasonally. In the Southwestern U.S., for most of the year the winds blow from the west/northwest. Arizona is located on the fringe of the Mexican Monsoon which during the summer months turns the winds to a more south/southeast direction and brings moisture from the Pacific Ocean, Gulf of California, and Gulf of Mexico. This moisture often leads to thunderstorms in the higher mountains and Mogollon Rim, with air cooled from these storms often moving from the high country to the deserts, leading to further thunderstorm activity in the desert. A common misuse of the term monsoon is to refer to individual thunderstorms as monsoons.

Objectives: Defined strategies or implementation steps intended to attain the identified goals. Unlike goals, objectives are specific, measurable, and have a defined time horizon.

100-Hundred Year Floodplain: Also referred to as the Base Flood Elevation (BFE) and Special Flood Hazard Area (SFHA). An area within a floodplain having a 1 percent or greater chance of flood occurrence in any given year.

Planning: The act or process of making or carrying out plans; the establishment of goals, policies, and procedures for a social or economic unit.

Power / Utility Failure: A power/utility failure is defined as an actual or potential shortage of electric power or the interruption of electrical power that significantly threatens health and safety. Many communities are vulnerable to many localized, short and long-term energy emergencies. Power shortages or failures do occur and may be brought on by severe weather conditions, such as blizzards, ice storms, extreme heat, thunderstorms, or events such as war, or civil disturbance.

Probability: A measure of how often events of a particular magnitude are expected to occur. Probability describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs. Statistically, a hazard with a 100-year recurrence interval is expected to occur once every 100 years on average, and would have a 1 percent chance – its probability – of happening in any given year. The reliability of this information varies depending on the kind of hazard being considered. May also be measured in terms of the chance that an event will be exceeded (or not exceeded) over a specified period of time. Frequency is a related term.

Q3 Data: The Q3 Flood Data product is a digital representation of certain features of FEMA's Flood Insurance Rate(FIRM) product, intended for use with desktop mapping and Geographic Information Systems technology. The digital Q3 Flood Data are created by scanning the effective Flood Insurance Rate(FIRM) paper maps and digitizing selected features and lines. The digital Q3 Flood Data are designed to serve FEMA's needs for disaster response activities, National Flood Insurance Program activities, risk assessment, and floodplain management.

Radiological Accident: A radiological accident is a release of radioactive materials. It can occur where radioactive materials are used, stored, or transported. Potentially nuclear power plants (fixed nuclear facilities), hospitals, universities, research laboratories, industries, major highways, railroads, or shipping yards could be the site of a radiological accident.

Radon: Radon is a naturally occurring radioactive gas that is odorless and tasteless. It is formed from the radioactive decay of uranium. Uranium is found in small amounts in most rocks and soil. It slowly breaks down to other products such as radium, which breaks down to radon. Radon also undergoes radioactive decay. Radon enters the environment from the soil, from uranium and phosphate mines, and from coal combustion. Radon has a radioactive half-life and about 4 days; this means the one-half of a given amount of radon will decay to other products every 4 days. Some of the radon produced in the soil will move to the surface and enter the air. Radon also moves from the soil and enters the groundwater.

Repetitive Loss Property: A property that is currently insured for which two or more National Flood Insurance Program losses (occurring more than ten days apart) of at least $1000 each have been paid within any 10-year period since 1978.

Richter Magnitude Scale: A logarithmic scale devised by seismologist C. F. Richter in 1935 to express the total amount of energy released by an earthquake. While the scale has no upper limit, values are typically between 1 and 9, and each increase of 1 represents a 32-fold increase in released energy.

Risk: The estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage beyond a particular threshold due to a specific type of hazard event. It also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment: A process or method for evaluating risk associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude and severity, exposure, and consequences.

Sabotage: Sabotage is the deliberate destruction of property, dismantling of technology or other interference or obstruction of normal operations. "Sabotage" is normally considered an act related to war; similar acts during "non-war" conditions would be considered a terrorist act.

Special Events: An event of such a magnitude, media visibility, or importance that may require extraordinary preparations by government and possible response by emergency response agencies. Such events may be considered an opportunity or target for activist or terrorist activities.

Strike: A strike is an organized work stoppage carried out by a group of employees for the purpose either of enforcing demands relating to employment conditions on their employer or of protesting unfair labor practices. A strike may be engaged to obtain improvement in work conditions, higher wages or shorter hours, to forestall an adverse change in conditions of employment, or to prevent the employer from carrying out actions viewed by workers as detrimental to their interests.

Subsidence: Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rocks falls in on itself.

Substantial Damage: Damage of any origin sustained by a structure in a Special Flood Hazard Area whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage.

Thunderstorms / High Winds: Thunderstorms are characterized as violent storms that typically are associated with high winds, dust storms, heavy rainfall, hail, lightning strikes, and/or tornadoes. The unpredictability of thunderstorms, particularly their formation and the rapid movement to new locations heightens the possibility of floods. Thunderstorms, dust/sand storms and the like are most prevalent in Arizona during the monsoon season, which is a seasonal shift in the winds that causes an increase in humidity capable of fueling thunderstorms. The monsoon season in Arizona typically is from late-June or early-July through mid-September.

Tornadoes / Dust Devils: A tornado is a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds in excess of 250 mph. Damage paths can exceed a mile wide and 50 miles long. Tornadoes are one of nature's most violent storms. In an average year, 800 tornadoes are reported across the United States, resulting in 80 deaths and over 1,500 injuries. The damage from tornadoes is due to high winds. The Fujita Scale of Tornado Intensity measures tornado / high wind intensity and damage.

A dust devil is a small but rapidly rotating column of wind made visible by the dust, sand, and debris it picks up from the surface. They typically develop best on clear, dry, hot afternoons and are common during the summer months in the desert portions of Arizona. While resembling tornadoes, dust devils typically do not produce damage, although in Arizona they have done so occasionally.

Terrorism (Economic, Cyber, Nuclear, Biological, and Chemical):"Terrorism is the unlawful use of force or violence, or threatened use of force or violence, against persons and places for the purpose of intimidation and/or coercing a government, its citizens, or any segment thereof for political or social goals." (Department of Justice, Federal Bureau of Investigation). Terrorism can include computer-based (cyber) attacks and the use of weapons of mass destruction (WMD) to include chemical, biological, radiological, nuclear, or explosive (CBRNE) agents.

Transportation Accident: A transportation accident is an incident related to a mode of transportation (highway, air, rail, waterway, port, harbor) where an emergency response is necessary to protect life and property.

Tropical Storms / Hurricane: A tropical system in which the maximum sustained surface wind ranges from 34 to 63 knots (39 to 73 mph). Tropical storms are associated with heavy rain, high wind, and thunderstorms. High intensity rainfall in short periods is typical. A tropical storm is classified as a hurricane when its sustained winds reach or exceed 74 mph (64 knots). These storms are medium to large in size and are capable of producing dangerous winds, torrential rains, and flooding, all of which may result in tremendous property damage and loss of life, primarily in coastal populated areas. The effects are typically most dangerous before a hurricane makes landfall, when most damage occurs. However, Arizona has experienced a number of tropical storms that caused extensive flooding and wind damage.

Volcanoes: A volcano is a vent in the Earth from which molten rock (magma) and gas erupt. The molten rock that erupts from the volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles. Volcanic eruptions can be placed into two general categories: those that are explosive and those that are effusive resulting in gently flowing lava flows, spatter cones, and lava fountains. Many eruptions are highly explosive in nature. They produce fragmental rocks from erupting lava and surrounding area rock and may produce fine volcanic ash that rises many kilometers into the atmosphere in enormous eruption columns. Explosive activity can also cause widespread ash fall, pyroclastic flows, debris avalanches, landslides, pyroclastic surges, and lahars.

Vulnerability: Describes how exposed or susceptible to damage an asset is. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power–if an electric substation is flooded, it will affect not only the substation itself, but a number of businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Vulnerability Analysis: The extent of injury and damage that may result from a hazard event of a given intensity in a given area. The vulnerability analysis should address impacts of hazard events on the existing and future built environment.

Vulnerable Populations: Any segment of the population that is more vulnerable to the effects of hazards because of things such as lack of mobility, sensitivity to environmental factors, or physical abilities. These populations can include, but are not limited to, senior citizens and school children.

Wildfires: Wildfire is a rapid, persistent chemical reaction that releases heat and light, especially the exothermic combination of a combustible substance with oxygen. Wildfires present a significant potential for disaster in the southwest, a region of relatively high temperatures, low humidity, low precipitation, and during the spring moderately strong daytime winds. Combine these severe burning conditions with people or lightning and the stage is set for the occurrence of large, destructive wildfires.

Winter Storms: Winter storm is defined as a cold wind accompanied by blowing snow; freezing rain or sleet, cold temperatures, and possibly low visibility and drifting snow. The storms often make roads impassable. Residents, travelers, and livestock may become isolated or stranded without adequate food, water, and fuel supplies. The conditions may overwhelm the capabilities of a local jurisdiction. Winter storms are considered deceptive killers as they indirectly cause transportation accidents, and injury and death resulting from exhaustion/overexertion, hypothermia and frostbite from wind chill, and asphyxiation.

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